Planta Tropika

0216 499X
E-ISSN: 2528-7079

Vol. 10 No. 1
February 2022

Jurnal Agrosains (Journal of Agro Science)

2528 7079 0216 499X

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Planta Tropika focuses related to various themes, topics and aspects including (but not limited) to the following topics Agro-Biotechnology, Plant Breeding, Agriculture Waste Management, Plant Protection, Soil Science, Post Harvest Science and Technology, Horticulture. Planta Tropika published two times a year (February and August) by Universitas Muhammadiyah Yogyakarta in collaboration with Indonesian Association of Agrotechnology / Agroecotechnology (PAGI). The subscriptions for one year : IDR 350.000.

Editorial Address

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List of Contents

Vol. 10 No. 1 / February 2022

2528 7079 0216 499X

Editorial

Journal of Planta Tropika ISSN 0216-499X published by Study Program of Agrotechnology, Faculty of Agriculture, Universitas Muhammadiyah Yogyakarta, is journal presenting scientific articles of agricultural science (Journal of Agro Science). With full sense of gratitude to the Almighty Allah, Volume 10 Number 1 for the year of 2022 has been published.
In this edition, Journal of Planta Tropika presents seven research articles in the field of Agro sciences comprising post harvest physiology, crop cultivation system, weeds management, tissue culture, land management, and climate. The scientific articles discuss about:

(1) The Yield Gap of Maize Under Intensive Cropping System in Central Java, (2) The Effectiveness of Oil Palm Empty Bunch Compost and Goat Manure on Shallots Cultivated on Red Yellow Podzolic Soil, (3) The Addition of *Trichoderma* sp. in Various Types of Organic Liquid Fertilizer to Increase NPK Nutrient Uptake and Soybean Production in Ultisol, (4) Determination of Agronomic Characteristics as Selection Criteria in Potato Crossing Lines, (5) Weeding Frequencies Improve Soil Available Nitrogen in Organic Paddy Field, (6) Epiphytic Weeds Control by Root Infusion Method in Oil Palm, (7) Histopathological Evaluation of Soybean (*Glycine max* (L.) Merr.) Strains Resistance to *Sclerotium rolfsii* Disease, (8) The Role of Indigenous Mycorrhizae of Corn Plants in Various Soil Types in Gunung Kidul, Indonesia, (9) Variability of Agro-morphological Character and Genotype Clustering of Watermelon [*Citrullus lanatus* (Thunberg) Matsum & Nakai] as Basic Selection for New Variety, and (10) Agrobiodiversity as Necessary Standard for the Design and Management of Sustainable Farming Systems

The editors would like to thank the authors, reviewers, executive editors, leaders and LRI UMY for their participation and cooperation. Our hope, this journal can be useful for readers or be a reference for other researchers and useful for the advancement of the agriculture.

Editors

GUIDE FOR AUTHORS

TYPE OF PAPERS

PLANTA TROPIKA receives manuscripts in the form of research papers in Bahasa Indonesia or English. The manuscript submitted is a research paper that has never been published in a journal or other publication.

SUBMISSION

The submission of the manuscript is done through our journal website http://journal.umy.ac.id/index.php/pt/index. If you need information regarding the process and procedure for sending the manuscript, you can send it via email at plantatropika@umy.ac.id. Editor's address: Program Studi Agroteknologi, Fakultas Pertanian, Universitas Muhammadiyah Yogyakarta, Jl. Ring Road Selatan, Tamantirto, Kasihan, Bantul, Telp (0274) 387646 psw 224, ISSN: 2528-7079.

ARTICLE STRUCTURE

The submitted manuscripts should consist of 15-20 pages of A4 size paper with 12-point Times New Roman fonts, 1.5 spacing with left-right margin and top-bottom of the paper is 2.5 cm each. All manuscript pages including images, tables and references should be page-numbered. Each table or picture should be numbered and titled.

The systematic of the manuscript writing is as follows:

TITLE : The title should be brief and informative and written bold. Only the first letter of the words is written in uppercase. Maximum length should be 14 words.

AUTHOR NAMES : The author names should be written in lowercase letters (only the first letter of the words is written in uppercase) and should be written from the first author and followed by the others along with the marker of each author's affiliation.

AUTHOR AFFILIATIONS : The author affiliation should be written in lowercase letters (only the first letter of the words is written in uppercase) and it is written according to the order of the number marker of each author's affiliation.

EMAIL : Please list one of authors' email address used for paper's correspondence.

ABSTRAK : Abstrak is written in Bahasa Indonesia using single space in a paragraph with maximum length of 200 words. It should contain background, objective, method, results, and conclusion followed by keywords containing maximum of 5 words.

ABSTRACT : Abstract is written in English using single space in a paragraph with maximum length of 200 words. It should contain background, objective, method, results, and conclusion followed by keywords containing maximum of 5 words.

INTRODUCTION : Introduction contains background, hypothesis or problem outline, and the objective of the research.

MATERIALS AND METHOD : Explaining in detail about materials and method used in the research as well as the data collection and analysis.

RESULT AND DISCUSSION : The results of the research should be clear. State the results collected according to analyzed data. Discussion should include the significance of the results.

CONCLUSION : Authors are expected to give brief conclusion and to answer the objective of the research.

ACKNOWLEDGEMENT : If necessary.

REFERENCES : Single space, according to the authors' guide of Planta Tropika.

EXAMPLES ON HOW TO WRITE REFERENCES

References are written in alphabetical order according to the rules below:

REFERENCE TO A BOOK

Gardner, F.P., R.B. Pearce, and R.L. Mitchell. 1991. Fisiologi Tanaman Budidaya (Translated by Herawati Susilo). UI Press. Jakarta.

REFERENCE TO A JOURNAL PUBLICATION

Parwata, I.G.M.A., D. Indradewa, P.Yudono dan B.Dj. Kertonegoro. 2010. Pengelompokan genotipe jarak pagar berdasarkan ketahanannya terhadap kekeringan pada fase pembibitan di lahan pasir pantai. J. Agron. Indonesia 38:156-162.

REFERENCE TO A THESIS/DISSERTATION

Churiah. 2006. Protein bioaktif dari bagian tanaman dan akar transgenic Cucurbitaceae serta aktivitas antiproliferasi galur sel kanker *in vitro*. Disertasi. Sekolah Pascasarjana. Institut Pertanian Bogor. Bogor.

REFERENCE TO AN ARTICLE IN PROCEEDING

Widaryanto dan Damanhuri. 1990. Pengaruh cara pengendalian gulma dan pemberian mulsa jerami terhadap pertumbuhan dan produksi bawang putih (Allium sativum L.). Prosiding Konferensi Nasional X HIGI hal. 376-384.

FIGURE FORMATTING

Title should be given **below each figure**. Additional information (notes) should be written in lowercase letters except the first letter in each sentence. All figures need to be numbered respectively. Figures should be placed close to explanation/ discussion about the figure.

Examples :

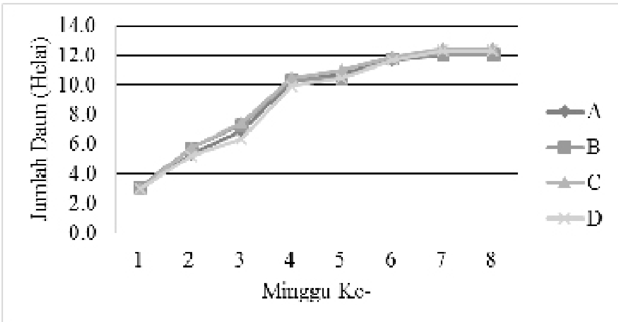

Figure 1. Number of leaves of corn plant

Notes:
A = 250 kg KCl/ha + 0 kg KJP/ha
B = 125 kg KCl/ha + 273,89 kg KJP/ha
C = 62,5 kg KCl/ha + 410,84 kg KJP/ha
D = 0 kg KCl/ha + 547,79 kg KJP/ha

Fig. 1., Fig. 2., and so on. The title of the figure is written with lowercase letters (use uppercase letter at the beginning of the title only) and without full stop (.). Additional information (notes) is placed below the figure.

TABLE FORMATTING

The title of the table should be written **above the table** started from the left (left alignment). Additional information related to the table (notes) is placed below the table. The information is written in uppercase letters at the beginning only as well as the titles inside the table. Table is placed close to the discussion of the table.

Examples :

Table 1. Fruit compost analysis

Variable	Jatropha before composted	Jatropha after composted	SNI (National standard) for compost	Category
Water content	22,49 %	45,79 %	≤ 50 %	Qualified
pH	7,05	8,02	4-8	Qualified
C-Organic content	10,01	5,11	9,8-32 %	Not qualified
Organic matter	17,42 %	8,81 %	27-58	Not qualified
N-Total	0,97 %	2,69 %	< 6 %	Qualified
C/N Ratio	10,44	1.90	≤ 20	Qualified
Potassium	-	9,06 %	< 6 %**	Qualified

Notes: **) Certain materials originated from natural organic matters are allowed to contain P_2O_5 dan K_2O level > 6% (proved with the results of laboratory analysis).

The Yield Gap of Maize Under Intensive Cropping System in Central Java

DOI: 10.18196/pt.v10i1.8789

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ABSTRACT

The study aimed to estimate the level of the yield gaps of maize in major producing areas, point out the causes of yield gaps in farmers' maize fields, and identify opportunities to the existing yield gaps through management practices of maize production in Central Java. This is the strategy for closing the existing yield gaps to achieve food self-sufficiency in agricultural land. Methods to estimates the yield gaps should cover data sources on physical conditions (weather and soil), management practices, and smallholder shapes. The relevant methods for estimating actual yields (Ya), potential (Yp), and water-limited (Yw) were compared. The yield gaps of maize under intensive cropping systems in rainfed ecosystems resulted in significant differences in all cultivation situations. The lowland rainfed maize showed Ya, Yp, and Yw values of 5.57, 12.83, and 12.47 ton/ha, respectively. The major causes of the yield gaps include variety, land preparation, and water issues concerned with the limited water inputs.

Keywords: Central Java, Intensification, Maize, Yield Gap, Yield Potential

ABSTRAK

Penelitian ini bertujuan untuk mengetahui tingkat kesenjangan hasil komoditas jagung di daerah produksi utama, menunjukkan penyebab kesenjangan hasil di lahan jagung petani, dan mengidentifikasi peluang untuk menutup kesenjangan hasil yang ada melalui budidaya jagung di Jawa Tengah. Ini adalah salah satu strategi untuk menutup kesenjangan hasil yang ada untuk mencapai swasembada pangan di lahan pertanian. Metode untuk menilai kesenjangan hasil menggunakan sumber data terkait kondisi fisik (iklim dan tanah), budidaya tanaman, dan pertanaman petani. Kami membandingkan metode yang relevan untuk memperkirakan hasil pada kondisi aktual (Ya), potensial (Yp), dan keterbatasan air (Yw). Kesenjangan hasil komoditas jagung pada sistem penanaman intensif di ekosistem tadah hujan menyebabkan perbedaan yang sangat besar di semua kondisi budidaya. Hasil penelitian jagung di dataran rendah tadah hujan memiliki nilai Ya sebesar 5,57 ton/ha, Yp sebesar 12,83 ton/ha, dan Yw sebesar 12,47 ton/ha. Penyebab utama kesenjangan hasil jagung adalah varietas, persiapan lahan, dan keterbatasan petani dalam input air.

Kata Kunci: Hasil Potensial, Intensifikasi, Jagung, Jawa Tengah, Senjang Hasil

INTRODUCTION

The world population in 2050 is forecasted to increase by 35%, reaching over nine billion. Indonesia has a high population growth rate (1.47% per year), and 75% of the population lives in Java (UN DESA, 2016). The needs for agricultural products, especially maize, must be met by increasing global production (Laborte et al., 2012). The need for maize farms is estimated to increase by 5%, up to 227 million hectares, in 2030 (CGIAR-SO, 2021). The global maize area is 197 million ha with an average production of 1,137 million tons from 2017 to 2019. Maize is cultivated mostly in developing countries (32%) (FAOStat, 2021). Indonesia is the 8th largest maize-producing country in the world. However, it is uncertain to what extent can be met considering the expected changes in diet and population (IFPRI, 2018).

The maize production faces the challenges of the land, water, and world food systems in a climate crisis. Future agriculture may produce more specific agricultural products such as maize (Erenstein et al., 2021). Limited agricultural land and water resources have prompted major investments in agricultural research and development to increase

Article History
Received: 08 May 2020
Accepted: 10 Sep 2021

maize production and achieve food self-sufficiency in existing farmland. Lowder et al., (2021) also argue that maize farming has important implications for understanding the development challenges associated with the global agri-food systems and eliciting appropriate policy responses.

On the other hand, maize also faces reactions related to the yield gap. The analysis of the yield gap is meaningful to look how large the gap is between actual yields in farmer fields and potential yields of varieties and identify water-limited yield factors (Rattalino Edreira et al., 2017). Yield potential (Yp) is described as the yield of a well-adapted crop cultivar with non-limiting nutrients and water. Biotic stresses in this condition are effectively controlled (Van Wart et al., 2013). The yield potential of a cultivar in an environment adjusts with nutrient and water supplies. It involves effectively controlling weeds, pests, and diseases. Crop growth in optimal conditions is determined by temperature, solar radiation, and CO_2 concentration. Management practices also impact crop cycle length of time and light interception, such as plant density, sowing date, and plant maturity (Van Ittersum et al., 2013).

Water-limited yield potential (Yw) is related to Yp, but it also considers the influence of water supply quantity and distribution during the growing season, as well as the soil properties controlling the crop water balance (Van Ittersum et al., 2013). Yw is determined by distribution and water supply during the growing season. This case usually occurs in rainfed systems, in which water supply from in-season rainfall and stored soil water is not enough to meet crop water needs (Rattalino Edreira et al., 2017). Yp and Yw models rely on the climate, soil, and management data to assume the influence of genotype, environment, and management practices on crop growth and yield (Rotter et al., 2015).

The yield gap of maize cropping systems in Indonesia represents 56% and 58% of Yp and Yw in irrigated and rainfed fields. The yield gap modeling is based on the local climate, soil, crop management, and farmers' maize yield data. At the national level, the average farmers' maize yield just ss 44% of 13 44% of 13 represents.6 ton/ha for the irrigated sites and 42% of 12.2 ton/ha in the rainfed fields. The yield gap is large enough due to uncertainties associated with land availability, irrigation expansion, the productivity of new land, and restrictions to modify crop sequences (Agus et al., 2019).

Closing the yield gap is a solution scheme to meet forthcoming maize demand. The potential yields are obtainable in spatial scale and specified cropping systems interest (Aramburu Merlos et al., 2015). Research on yield gaps in maize is still limited. The last studies about yield gaps in Central Java only revealed the value of rice commodities. The research has not explained any systematic effort to understand the causes and the value of yield gaps in maize (Boling et al., 2010).

Without a joint effort to measure maize yield gaps and understand their underlying explanatory factor, it will be difficult to orient and prioritize investments on interventions targets to close current yield gaps and increase food production in existing cropland areas. Self-sufficiency and opportunities for annual productivity can be achieved and identified, respectively, by closing the yield gaps. This study aimed to estimate the level of the yield gaps of maize in major producing areas, point out the causes of yield gaps in farmers' maize fields, and identify opportunities to close the existing yield gaps through management practices of maize in Central Java.

MATERIALS AND METHODS

This study was carried out in Grobogan, Central Java. The study sites represented irrigated lowland and rainfed upland ecosystems of maize (*Zea mays*).

This study was conducted in two stages. The first stage was to estimate the level of the yield gaps of maize in major producing areas (April–November 2017). The second stage was to point out the causes of yield gaps in farmers' maize fields in Central Java and identify opportunities to close the existing yield gaps through management practices (April-August 2018).

The range of maize yield and management in the farmers' fields was collected from on-farm. This major survey was performed to estimate the level of the yield gaps from the farmer's fields planted with maize over two crop seasons (2017 and 2018) in both wet and dry seasons. This study was carried out to assess variation in the selected farmers' fields. Yield gaps were investigated by figuring out data on maize grain yield, crop management practices, crop management, applied inputs, and production site adversities. Data were collected from multiple personal interviews with farmers in the course of over two agricultural seasons in the selected areas. Protocol based on Grassini et al., (2015) related to Global Yield Gap Atlas was used.

Supporting data sources in the form of climates (rainfall, temperature, humidity, and solar radiation) were collected during the last 18 years (2000-2017) from Semarang weather station, Indonesian Agency for Meteorology, Climatology, and Geophysics, and NASA POWER service. Data on the maize harvested area and average farmer yields were taken from 2010 and 2015 from Indonesian National Statistics. The soil data, description of annual cropping sequence, and crop system of study sites were available from the Ministry of Agriculture and local offices to support the research.

Low-yield and high-yield field classes were recognized based on their relevant presence in the lower and upper quartiles of the field yield distribution. Differences in each applied input and management practice between the low-yield and high-yield fields were assessed using t-tests. Association between categorical variables and field level was appraised using Chi-square (x^2) tests (Stuart et al., 2016).

The second stage was a survey to identify the causes of the yield gaps. This technique was done using a stratified random sampling following the order of Province, Regency, Villages, Farmers, Fields, Years, and crop cycles. Five villages were selected according to the crop, while 20 farmers were selected for interview within each village. Hence, the total number of surveyed fields was 100 for the entire Central Java Province.

The interview method used was a face-to-face interview. The interviewer was provided with returned studies handed out by agronomists, agricultural extension educators, crop consultants, technicians, and researchers with guidelines to collect the data. The collected data also covered field location in the form of a face-to-face interview. The interviewer was provided with returned studies handed out by agronomists, agricultural extension educators, crop consultants, technicians, and researchers with guidelines to collect the data. The collected data also covered field location in the form of e pictures of the field taken in every corner of the farmers' fields for high accuracy location.

The survey design was determined based on the selection criteria for provinces, districts, villages, and farmers (Table 1). The study also aimed to identify opportunities to close the existing yield gaps through management practices.

The farmers are represented in the range of farmers in the local area. The farmers' maize fields data were selected not from the experimental sites, trial plots, and variety-testing plots. Farmer maize field is defined as a plot of land planted with maize managed with equal practices (e.g., planting/transplanting date, fertilizer amount and timing, variety choice, plant density) and harvested at the same time. The collected data were avoided from

Table 1. Design survey to identify the causes of yield gaps

Stratified random sampling	Detail	Information
Province	Central Java	Province was determined based on crop-specific harvested areas.
Regency (1)	Grobogan	Regency was selected based on: 1) large maize harvested area; 2) overlapping with study area from the first stage of the project; 3) availability of meteorological station; 4) logistically viable.
Villages (5 per Regency)	Depok, Kalongan, Karanganyar, Ngraji, Tambirejo	Villages were selected based on the 1) representation of dominant crop sequence; 2) distance between village at least 10-15 km to avoid overlapping.
Farmers (20 per Village)	Total 100 Farmers	Farmers were selected based on the 1) represented dominant soil types and crop sequence; 2) represented range of socio-economic conditions; 3) reasonable approachability to field visits; 4) farmers' interest in participating in the research schemes
Fields (1-3 per Farmer)	Total 100-300 Fields	Fields selection reflected the most typical farm management practices and cropping systems in the area
Years (2)	2017 and 2018	Yield and management practices data were collected from fields planted with maize during 2017 and 2018
Crop Cycles (2-3 per Year)	Rice-Rice-Maize	Data included the 2-3 crop cycles including maize within each year

lands planted with more than two varieties, or fields with portions planted at very different dates (more than a four-day difference). Outlier lands, fields not representing the range of management practices within the country, including organic farms, fields following typical crop sequences, or fields severely affected by unavoidable factors such as storms, rats, flooding, lack of water in irrigation schemes, suffered severe drought, and insect/disease damage. Maize grain yields (without cob) were reported at 15% moisture content.

The analysis for management practices implicating more than two distinguishable ways was classified into two categories. Variables showing significant effects on the yield, as expressed by the comparability between low-yield versus high-yield fields, were further investigated. Quantitative regression was used to derive limits for the relationship between delay in sowing date and farmer yield using the R program. Paired t-tests were used for categorical variables (e.g., tillage), and mean yields were calculated for different management categories (e.g., fields with versus without tillage). ANOVA was conducted to assess the impact of yield in each regency, village, and farmer. Analysis of Pearson's correlation, based on the meteorological factors projected for each crop phase in the region (independent variables) and yield responses to different management factors (dependent variables), was performed to explore the biophysical basis for management and environment interactions (Rattalino Edreira et al., 2017).

RESULTS AND DISCUSSION

The Climates and Soils Orders of the Study Site

The study areas were selected to point out the causes of yield gaps in the farmers' maize fields in Grobogan, Central Java. This region has a major crop sequence of Rice-Rice-Maize (60%). The production data were also collected to identify the largest crop area within Central Java Province. The fields that match the spatial locations of our study sites were selected for the project. Crop-specific harvested areas, lowland rainfed maize in Central Java, selected weather stations, and study areas around them were used to estimate the level of the yield gaps of maize in major producing areas.

Secondary data were used as the major references of weather data. The data on daily rainfall, minimum and maximum temperature, humidity, and solar radiation during 2000-2017 were collected and used to release weather data with quality control based on the relationship between adjacent weather stations and selected weather stations. Total annual rainfall was more than 2,730 mm in most locations. Tropical climate conditions in Grobogan, Central Java are good for growing complex crop systems in the same year on the same land. The agroecosystem at the study site is characterized by reliable distributions of rainfall patterns and strong weather (Figure 1 and 2).

During the last 18 years (2000-2017), the weather data from the target surveys are illustrative for the zone. The growing season of maize lasts from July to September. The minimum temperature of the study site in the last decade is around 21.2 °C, while the maximum temperature is about 32.9 °C. The average temperature at that location ranges from 19.5 to 27.9 °C. Total annual rainfall ranges from 715.8 mm, and more than 2730 mm is in most parts of the area of lowland rainfed maize. The average humidity ranges from 52.1-79.7%.

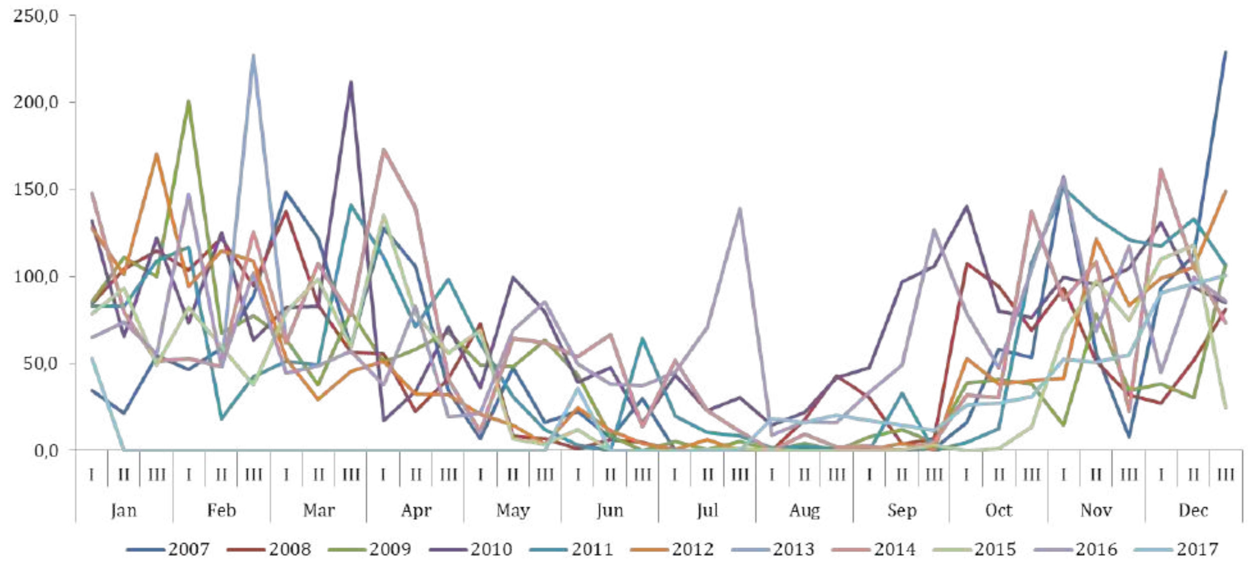


Figure 1. Trend rainfall in Grobogan, Central Java 2007-2017

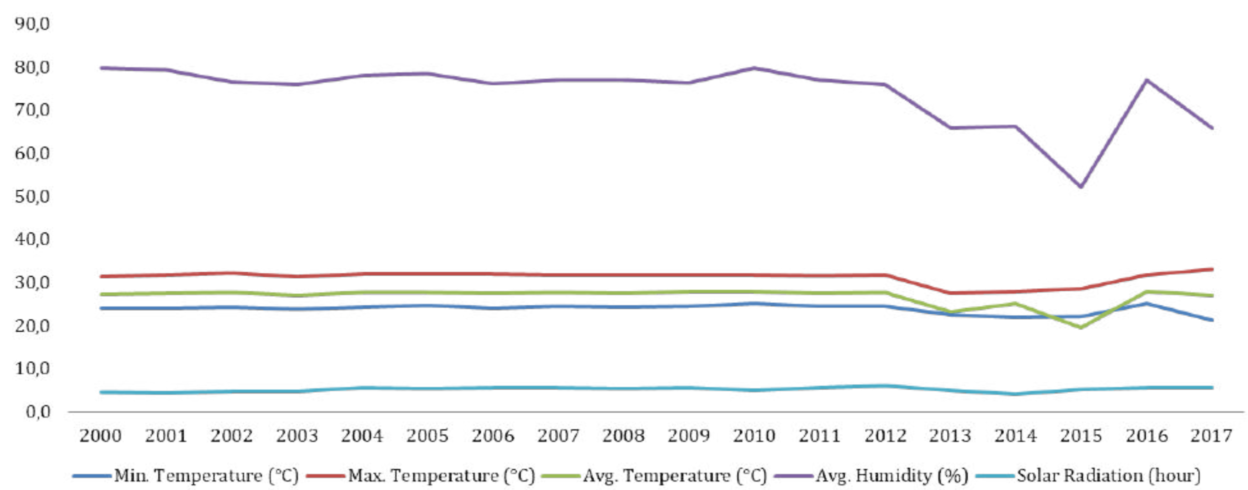


Figure 2. Temperature, humidity and solar radiation in Grobogan, Central Java 2000-2017

Table 2. Annual cropping sequence in Grobogan, Central Java

Low land/ Up land	Annual cropping sequence	% Crop area under this sequence	Crop	Water regime	Sowing window	Trans planting window	Flowering window	Maturity window	Domi-nant variety/ hybrid	Plant density	Dominant soil types	Soil type description			% Sequence under each soil type
												Texture	Root Depth (cm)	Slope	
Irrigated Lowland	Rice-Rice-Maize	25%	Rice	Fully irrigation (Wet Season)	Sept 15 up to Oct 15	Oct 05 up to Oct 30	Nov 25 up to Dec 20	Jan 15 up to Feb 10	Ciherang	(20x20) cm 2-3 plants/ hill	Vertisols	Clay	>100 cm	0-3	80
			Rice	Fully irrigation (Wet Season)	Jan 15 up to Feb 10	Feb 5 up to Feb 30	Mar 25 up to Apr 20	May 15 up to June 10	Ciherang	(20x20) cm 2-3 plants/ hill	Inceptisols	Clay	50-100	0-3	20
			Maize	Manual watered and rainfed (Dry Season)	May 20 up to Jun 15		July 10 up to August 5	August 30 up to Sept 25	P21	(80x40) cm or (40x40) cm, 2 seeds/hill cm, 1 seed/ hill					

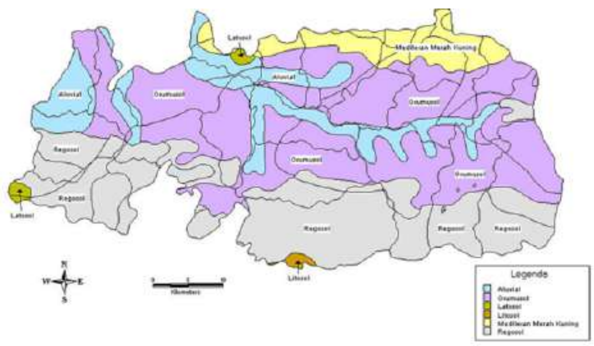


Figure 3. Dominant soil orders in Grobogan, Central Java

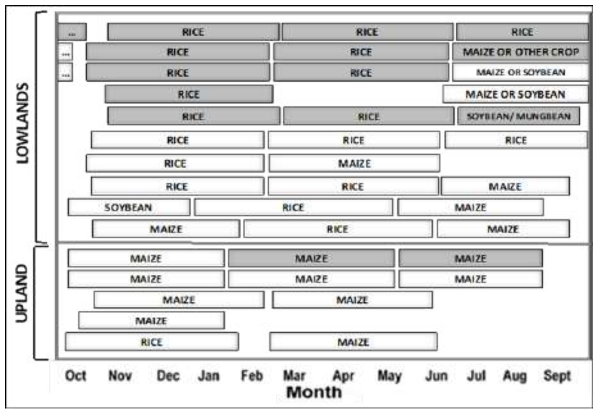


Figure 4. The complex crop systems in Central Java (October – September)

During the growing season, solar radiation in the study area varies from 4.2 to 5.0 MJ/m^2/day (Figure 3). The variability in temperature and rainfall conditions, excluding potential limiting factors, can give different estimates (Sheehy et al., 2006).

The medium-resolution soil maps were used to guide the selection of the villages in the location to ensure that their sites match the dominant soil maps in each region. Soil properties for the dominant agricultural soils in each buffer can be seen in Figure 3. Dominant agricultural soils in the lowlands area are Grumusol and Regosol. Grumusol is black soil, suitable for agriculture, and rich in calcium and magnesium. Meanwhile, Regosol is a very weakly developed mineral soil in unconsolidated materials. Soil map was used to identify

Table 3. Description of crop system in Grobogan, Central Java

RWS name	Landscape	Water regime	Crop name	Growing season	Average grain yield (ton/ha)
Semarang	Lowland	Irrigated	Rice	October-February	7.15
Semarang	Lowland	Irrigated	Rice	February-June	5.31
Semarang	Lowland	Manual watered and rainfed	Maize	June-September	6.22

Remarks: RWS=Reference Weather Stations

Table 4. Yield and water productivity levels of rainfed maize fields in Central Java

Harvest year	Ya	Yw	Yp	WPP	WPA	Information	
2000	-	12.97	12.97	31.75	-	Station	Semarang
2001	-	12.71	12.71	30.44	-	Longitude	110.511
2002	-	12.58	12.61	30.39	-	Latitude	-7.247
2003	-	12.68	12.72	30.62	-	Crop	Rainfed maize
2004	-	12.98	13.02	31.17	-	Management	Lowland irrigated rice-rice rainfed maize
2005	-	12.85	12.92	30.66	-	Crop cycle	3
2006	-	12.21	12.86	29.73	-	Harvest year	2000-2015
2007	-	12.65	12.85	31.06	-	Sowing date	05-Jun
2008	-	10.72	12.73	27.82	-	Cultivar maturity	1800
2009	-	11.86	12.40	29.82	-	Plant density	80
2010	4.62	12.65	12.70	30.84	11.26	Used model	Hybrid Maize 2017
2011	5.54	12.50	12.73	30.58	13.56	Cropping intensity	1.3158
2012	5.71	13.02	13.02	31.12	13.66	YW_CV temporal	0.0525
2013	5.83	11.30	13.17	28.64	14.77	YP_CV temporal	0.0151
2014	5.95	12.98	13.05	31.23	14.32	YA_CV temporal	0.0874
2015	5.78	12.87	12.87	30.86	13.86	Climate zone	9901
Mean	5.57	12.47	12.83	30.42	13.59	Area in Climate zone (Ha)	69105

Remarks: Ya is the actual yield (kg/ha), Yp is the simulated yield potential (kg/ha), Yw is the simulated water-limited yield potential (kg/ha), WPP is water productivity potential (kg/ha/mm), WPA is water productivity actual (kg/ha/mm), and CV is the coefficient of variation. The unit of the yield levels (Ya, Yp, and Yw) is tons per harvested hectare at standard moisture content. The unit of the water productivity levels (WPP and WPA) is kg per mm water per hectare.
Source: http://www.yieldgap.org/gygamaps/excel/GygaModelRunsIndonesia.xlsx

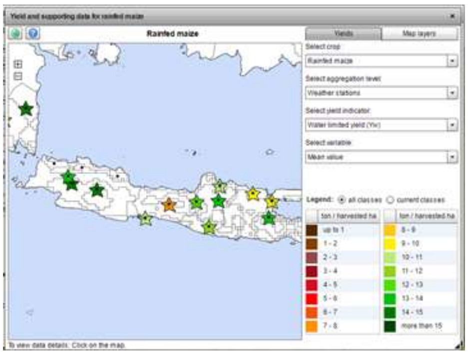
the dominant agricultural land, and the 1:50,000 scale map was used to compute the lowland area.

Cropping Pattern of Study Site

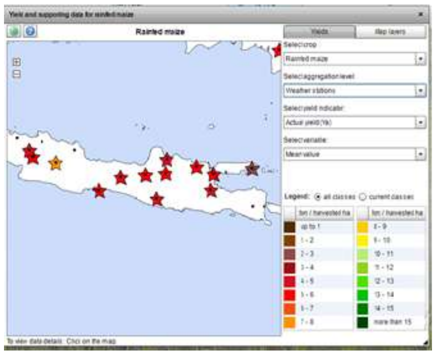
Annually, Central Java has a cropping system with an intensity that varies from one to three crops, for example, rice-rice-maize. The rainy season for most areas in Central Java starts from October and continues until March (Figure 4). The annual cropping sequence in Grobogan, Central Java is Rice-Rice-Maize with 25% crop area. This study focused on the rainfed lowland maize. Dominant water regimes are annual watered and rainfed (dry Season). The estimated sowing is on May 20 to June 15 without transplanting, flowering date ranged from July 10 to August 5, and ripening stage started from August 30 to September 25. The dominant corn variety used was Bisi products. Farmers used plant densities of (80x40) cm or (40x40) cm, with one or two seeds per clump (Table 2).

The Level of the Yield Gaps of Maize

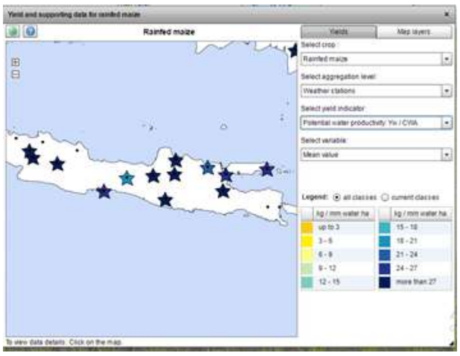
The data on lowland areas in the regency level were obtained for rice and maize. The harvested area reported for each site has a function to estimate the average yield of the farmers based on regencies that overlap with the location of the buffers. The information obtained from official statistics, local extension agents, and agronomists were useful to assess grain yields and areas of maize



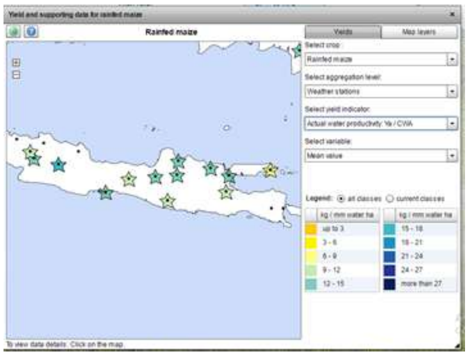
Water Limited Yield (Yw) 12-13 ton/harvested/ha



Actual Yield (Ya) 4-5 ton/harvested/ha



Potential Water Productivity (Yw)/CWA more than 27 kg/mm water ha



Actual Water Productivity (Ya)/CWA 15-16 kg/mm water ha

Cropping intensity for this crop 1.45-1.60 harvests per year

Maize on major producing areas

Figure 5. Yield and supporting data for rainfed maize, select aggregation level by the weather station. Source: http://www.yieldgap.org

for rainfed lowland.

In the study area, an overview of the context of the cropping system was obtained by taking 2010 and 2015 data from RWS Semarang in the lowland landscape. There are two types of water regimes, namely manual and rainfed irrigation. This region's most common cropping sequence is rice-rice-maize, with an average grain yield of 7.15, 5.31, and 6.22 ton/ha, respectively (Table 3).

The lowland rainfed maize fields at late stage of harvest is prone to drought. There are high risks associated with landscapes, seasons, groundwater depth across sites, and predisposing factors to maize yields. Both scenarios simulated the water-limited

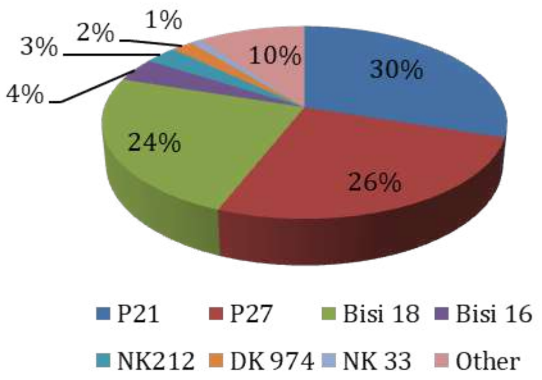


Figure 6. Maize' varieties used by farmers

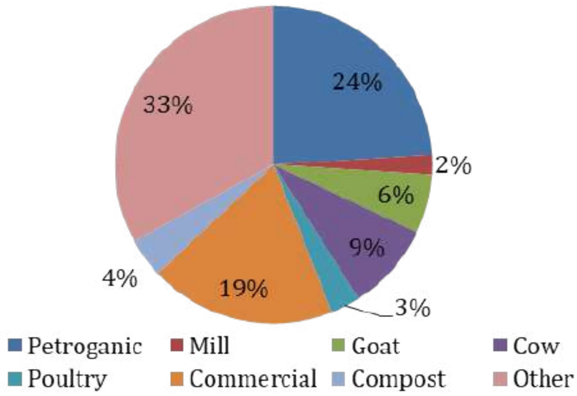


Figure 7. Manure sources applied by farmers

yield potential for lowland rainfed maize over the entire crop cycle. The first is a groundwater depth of 150 cm (deep), mainly describing drought-prone (deep) environments. The second is 10 cm (shallow), which describes non-water limiting (shallow) environments.

Rainfed maize fields in Central Java have Water Limited Yield (Yw) of 12-13 ton/harvested/ha and Actual Yield (Ya) of 4-5 ton/harvested/ha, ranging from 4 to 15 ton/harvested/ha across locations. The current yield gap is 5.57 ton/ha (60% of the potential). Crop Availability Water (CWA) is the amount of water supply during the growing season. The potential Water Productivity in Central Java (Yw)/CWA is more than 27 kg/mm water ha (30.42), and Actual Water Productivity (Ya)/CWA is 15-16 kg/mm water ha. Major producing areas of maize have a cropping intensity of 1.45-1.60 harvests per year (Table 4 and Figure 5).

Lowland rainfed maize in Central Java is technically not irrigated. During most of the growing season, soil properties remain undersaturated and regarded as non-water limited. Affholder et al., (2013) argue that potential yields of primary food crops, especially maize, are under rainfed in the tropics, which mostly does not show good results. Soil properties and rainfall influence the groundwater balance for rainfed plant growth. The water-limited maize yields can be around 25%.

The Causes of Yield Gaps in Farmers' Maize Fields

The survey data obtained from the maize farmers were provided for management practices and to inform the average maize yield for each of their fields in each year. The proposed management practices for each RWS (Reference Weather Stations) include the dominant crop sequences, ecosystems, water regime, total harvested area, maize management (sowing and transplanting date, actual and optimal maize population density and spacing, variety, and tillage system), applied inputs (nutrient fertilizer, lime, irrigation, manure, and pesticides), and extent of abiotic and biotic stresses (flood, diseases, insect).

The results showed the maize varieties used by farmers during the 2017-2018 period. There are six hybrid maize varieties commonly used in lowland areas (Figure 6).

The basic cross-correlation analysis of yield gaps describes the causes of the yield gaps at the field scale. The indicators used include data crop management, soil constraints, and biotics. The aftermath of various factors on the growth of maize and other results of crop population, nutrition, and water limitations were evaluated separately. Table 5 indicates there may be a large space for maize yield

Table 5. The causes of yield gaps in farmers' maize fields

Management practices	Farmer's method	Management practices	Farmer's method
Air drying	after	NPK per ha	279.38 kg
Establishment	direct	ZA per ha	279.38 kg
Straight row method	no	SP36 per ha	2.08 kg
Between row	59.85 cm	Urea per ha	371.91 kg
Within row	40.25 cm	N rate application	225.59
Plant per hill	1.99	Manure rate application	9.24
Seeding rate	3.13	Fungicide rate application	0.38
Establishment (month)	6	Insecticide rate application	0.83
Establishment (day)	12	Hormones rate application	0.04
Harvest (month)	9	Fertilizer rate application	0.44
Field Area on google earth	279.03	Weeding manual/mechanic	0.63
Yield	5.56 t	Weeding chemical application	0.93

Table 6. Famers management practices

Information	Farmer's method	%
Land preparation	no-tillage	48
	minimum	47
	full	5
Pumped water	no	65
	yes	35
Lime and manure	none	6
	manure	93
	both	1
Straw management	removed	75
	left	25
Straw burning	unburn	46
	burned	54
Water issues	none	53
	deficit	45
	excess	2

improvement due to the new actual yield chance. The farmers should shift from traditional to modern varieties suited to solve farming problems and improve market demand for yield grain. The maize production dominated by smallholder farming systems shows management practices in Central Java using N sources such as NPK and urea with an N rate of application (Table 5). The study of Leitner et al., (2020) explains that increasing soil fertility and closing the yield gap by 75% could be through increased N fertilizer. This application rate is expected up to 35% of current maize yields.

Management for improving soil fertility and ecological regulation requires the availability of organic matter and plant nutrients, especially phosphorus and nitrogen. Farmers' crop management applies several sources of organic manure from the surrounding area (Figure 7). The crop production will benefit from the addition of organic material and manure according to the recommended dosage. The combination of organic and chemical fertilizer can support a high grain yield of maize. This application is also useful for mitigating the negative impact on the environment (Zhang et al., 2021).

The results of interviews with farmers show that land preparation is dominant with the no-tillage method before planting. Most farmers apply watering management without a pump, and few use pumped water (Table 6). The maize yield is highly sensitive to water source capacity. The lowest maize yield was related to the lowest water source capacity. Guidance is needed to identify and prioritize the most appropriate strategies for optimizing yields and water management (Araya et al., 2021).

Table 6 showed that most farmers apply manure, remove the straws from the field, and burn the stalks after harvest. Half of the farmers don't have any problems in water issues, while the rest experiences water deficit and excess (Table 6). Study areas were used to identify the causes of yield gaps in Central Java, based on the cropping sequence Rice-Rice-Maize (60%). The estimated planting seed was from May 20 up to June 15.

For instance, Affholder et al., (2013) stated that cropping management with low density on fields had a greater negative effect on the maize yield. The relatively higher global radiation could be profitable at an early stage of maize growth. Maize cultivation is more favorable in the competition for nutrition, water, and light at the end of the season.

CONCLUSIONS

The tropical climate of Central Java is feasible to grow complex crop systems on the same plot of land in the same year. The yield gaps of maize under intensive cropping systems in rainfed ecosystems cause variation between cultivation situations. The rainfed maize field in the lowland area in Central Java showed a Potential Yi variation between cultivation situations. The rainfed maize field in the lowland area in Central Java showed a Potential Yie variation between cultivation situations. The rainfed maize field in the lowland area in Central Java showed a Potential Yield variation between cultivation situations. The rainfed maize field in the lowland area in Central Java showed a Potential Yield variation between cultivation situations. The rainfed maize field in the lowland area in Central Java showed a Potential Yield (Yp) of 12.83, ranging from 4 to 15 ton/ha. Meanwhile, the Actual Yield (Ya) was 5.57, reaching 4-5 ton/ha per harvest, and the Water Limited Yield (Yw) was 12.47, reaching 12-13 tons/ha. The current yield gaps in major producing areas are re5.57 ton/ha (60% of the potential). Maize production in major areas has a cropping intensity of 1.45-1.60 per year. The causes of the yield gap from farmers are on-farm data that well describe the range of maize yield and management across farmers' fields. The major causes of yield gaps in farmers' maize fields are variety, land preparation, and water issues concerned with the incapacity of farmers to water inputs. Understanding the mechanism leading to the yield gap can accelerate the reach of self-sufficiency and increase opportunities for annual maize productivity to close the existing yield gaps through management practices of maize.

ACKNOWLEDGEMENTS

The authors are grateful for the financial support through Global Yield Gap Atlas Indonesia Project from Indonesian Agency for Agricultural Research and Development. Gratitude is expressed to Prof. Patricio Grassini (University of Nebraska–Lincoln, USA) and Prof. Fahmuddin Agus (Center for Agricultural Land Resources Research and Development) for insightful comments on this research. The authors also thank Yuni Kamal and Warsito (Assessment Institute for Agricultural Technology of Central Java) and Agricultural Extension from Grobogan Regency for excellent support in the fields.

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The Effectiveness of Oil Palm Empty Bunch Compost and Goat Manure on Shallots Cultivated on Red Yellow Podzolic Soil

DOI: 10.18196/pt.v10i1.10621

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ABSTRACT

Red yellow podzolic (RYP) soil is one of the limiting factors in crop cultivation due to its high level of acidity and low content of essential nutrients. This study aimed to explore the effect of oil palm empty bunch (OPEB) compost and goat manure on shallots cultivated on RYP soil, determine the best treatment combination as fertilization recommendation, and analyze the economic feasibility for organic shallot farms. Observations were conducted on soil pH, crop growth, crop yield, shallot farm economic analysis, and the fertilization effectiveness calculation. The results demonstrated that the fertilization had a significant interaction effect on crop height, number of tillers, and fresh and dry tuber weights, but not on the soil pH, number of leaves, and tubers per cluster. A combination of 4 ton/ha compost and 1,00 ton/ha manure resulted in optimal production of dry tubers reaching 0.708 kg/plot (2.36 ton/ha). Meanwhile, the highest production of dry tubers of around 0.990 kg/plot (3.30 ton/ha) resulted from the combination of 5 ton/ha compost and 1.25 ton/ha manure. Farm analysis showed that organic fertilizer applications provided economic profit, indicated by R/C Ratio value greater than 1. The effectiveness of organic fertilization using compost and manure reached the highest values of 318.90% and 384%, respectively.

Keywords: Effectiveness, goat manure, OPEB compost, RYP soil, shallot

ABSTRAK

Tanah podsolik merah kuning (PMK) merupakan salah satu faktor pembatas budidaya tanaman karena memiliki derajat keasaman tinggi dan rendah kandungan unsur hara esensial bagi pertumbuhan tanaman. Penelitian ini bertujuan untuk menganalisis pengaruh pemberian kompos tandan kosong kelapa sawit (TKKS) dan pupuk kotoran kambing terhadap pertumbuhan dan hasil tanaman bawang merah pada tanah PMK, kombinasi perlakuan terbaik yang dapat menjadi rekomendasi pemupukan, dan kelayakan ekonomi usahatani bawang merah organik. Pengamatan dilakukan terhadap beberapa komponen, yaitu pH tanah, pertumbuhan tanaman, hasil tanaman, analisis ekonomi usahatani bawang merah, dan perhitungan efisiensi pemupukan. Hasil penelitian menunjukkan bahwa perlakuan pemupukan menghasilkan interaksi nyata terhadap tinggi tanaman, jumlah anakan, bobot umbi segar, dan bobot umbi kering, tetapi tidak menghasilkan interaksi nyata terhadap pH tanah, jumlah daun, dan jumlah umbi per rumpun. Kombinasi 4 ton/ha kompos dan 1,00 ton/ha kotoran kambing menghasilkan produksi optimal umbi kering bawang merah 0,708 kg/petak (2,36 ton/ha). Kombinasi 5 ton/ha kompos dan 1,25 ton/ha kotoran kambing menghasilkan produksi tertinggi umbi kering sebesar 0,990 kg/petak (3,30 ton/ha). Analisis usahatani memperlihatkan bahwa penggunaan pupuk organik memberikan keuntungan ekonomi dengan nilai R/C Ratio yang lebih besar daripada 1. Efektivitas pemupukan organik untuk kompos dan pupuk kandang mencapai nilai tertinggi masing-masing sebesar 318,90% dan 384%.

Kata kunci: *Efektivitas, Pupuk kotoran kambing, Kompos TKKS, Tanah PMK, Bawang merah*

INTRODUCTION

Shallot is an important horticultural commodity due to its nutritional content, economic value, and benefits as a daily cooking spice. One of the shallot-producing regions in Central Sulawesi Province is Poso Regency, comprising North Lore, East Lore, Lore Peore, North Pamona, and Pamona Puselemba Districts. The highest yield-per-hectare is produced in East Lore (4.94 ton/ha), while the lowest one is from North Pamona (0.76 ton/ha) (Regency, 2017). This production is lower than yield-per-hectare in Central Sulawesi and shallot's potential productivity, which are 5.31 ton/ha (Sulteng, 2017) and 10–20 ton/ha (Purba, 2016), respectively.

According to Erpina et al., (2013), one of the limiting factors for shallot growth is soil fertility, influenced by the availability of nutrients, organic materials, and soil types. Specifically for

Article History
Received: 16 Dec 2020
Accepted: 01 Sep 2021

North Pamona and Pamona Puselemba regions, preliminary surveys indicated that the land used for shallot planting was generally the Red Yellow Podzolic (RYP) soil type, which had high acidity and low N, P, and K contents. Yields and qualities of shallots cultivated on RYP soil and commonly fertilized with NPK were usually very low, ranging from 0.6-0.9 ton/ha or 0.76 ton/ha on average, thus reducing farmers' interest in cultivating them.

Red Yellow Podzolic is a type of soil formed by a pedogenesis process that resembles the formation of latosol soil. It has a soil organic material thickness less than 60 cm, some of which are still decomposing, and has many fibers. Red Yellow Podzolic soil agroecosystem deals with many obstacles, especially dry areas with high slopes because RYP soil is sensitive to erosion (Raiwani et al., 2016). The constraints faced on RYP soil include low soil pH (4.1-4.8), high Al, Fe, and Mn solubilities but low P and Mo availabilities, the dominances of kaolinite clay minerals, Fe oxides, and Al so that the soil has a low cation exchange capacity, and high mineral contents, which if dissolve will cause cation saturation that is toxic to crops, while the anions are easily fixed so that they become unavailable to crops (Ramadhani et al., 2015).

Due to high rainfall, red Yellow Podzolic soil has undergone further weathering with a very intensive leaching process. The result is low contents of exchangeable bases (< 35 %) and organic materials (C/N ratio 5-10) (Tando, 2020). Red Yellow Podzolic soil requires organic materials to improve the soil's physical, chemical, and biological properties. The addition of organic materials can reduce Al solubility and enhance the availability of essential nutrients such as N, P, and K (Erpina et al., 2013). According to Tando (2020), RYP soil has the potential to be used as a medium for crop growth because it has a medium to high cation exchange capacity (>16 cmol/kg), so it helps the fertilization. In addition, to the cross-sectional conditions of the soil that are deep enough to support crop roots.

Oil palm empty bunch (OPEB) and goat manure are natural ingredients utilized as organic fertilizers. Oil palm empty bunch is the source of organic potassium (K), containing up to 2.90 % (Firmansyah, 2010). The high levels of K, which are alkaline, can raise soil pH, reducing soil acidity. For shallot crops, K elements are needed, particularly in tuber formation. The N content in goat manure reaches 1-2 %, stimulating initial crop growth (Prasetyo, 2014). The use of OPEB and goat manure is an effort to use agricultural wastes into efficient products and reduce external farming inputs.

Through the decomposition process, OPEB can be used as fertilizer which high N, P, and K content (Kurniawan et al., 2014). Nutrients contained in OPEB include 2.90 % K_2O, 0.80 % N, dan 0.22 % P_2O_5 (Firmansyah, 2010). OPEB compost has a high K content, which can improve physical, chemical, and biological soil properties and enrich nutrients (Elfiati & Siregar, 2010). Research results by Sukasih (2017) demonstrated that OPEB application as many as 1.5 kg/m^2 resulted in the best average of spring shallot height per cluster, which was 18.87 cm and 32.00 cm, respectively, the number of leaves per cluster of 11.40, and fresh weight per cluster of 102.00 gram.

Livestock manure is the most significant waste produced in animal farming. One method of avoiding environmental pollution caused by livestock waste is to convert it into manure (Kusuma, 2012). Goat manure has an N content of 1-2%, P 0.8%, and K 0.4%. The reasons for using goat manure are that it is easy to obtain, has high N content, and is a hot fertilizer. Hot fertilizer is a fertilizer whose decomposition is conducted by soil microorganisms so quickly that the nutrients contained in it can be rapidly utilized by crops (Prasetyo, 2014). The problem with manure application is the reluctance of farmers to use manure because the organic material is available slowly to the soil. Therefore, manure application is directed to fertilizers that have been fermented with bio activators, such as effective microorganisms 4 (EM4), so that they can have a good, fast, and direct effect on crop growth and yield (Suwandi et al., 2015).

Sumarni et al., (2012a) stated that growing and producing shallot crops required adequate and balanced nutrient availability, particularly N and K. N and K nutrients, which are essential for the growth, development, and yield of shallot bulbs. N nutrient is a building block for proteins, nucleic acids, enzymes, nucleoproteins, and alkaloids. N deficiency limits cell division and enlargement. High doses of N fertilizer do not provide significant results on shallot production. Onion production increases only 32% if N application is twice as high as the previous dosage (Napitupulu & Winarto, 2010). In other words, applying high doses of N fertilizer does not guarantee an increase in yield.

The results of research on shallot fertilization indicate that fertilizer requirements for shallot bulb production vary between 150-300 kg/ha N, 90-180 kg/ha P_2O_5, and 50-150 kg/ha K_2O, depending on the variety, growing season, and soil type (Sumarni et al., 2012b). Purba (2016) concluded that the application of inorganic fertilizers and organic fertilizers significantly increased the growth and yield of shallot tubers. The combination of artificial organic fertilizer 5 ton/ha with Urea 100 kg/ha, SP 36 200 kg/ ha, and NPK Phonska 300 kg/ha gave the highest tuber yield (15.022 ton/ha), R/C ratio (1.93), and profit of Rp 79,276,000 per hectare. The value of R/C Ratio >1 indicates that shallot farming is economically profitable. Through this research we try to point out the effect of organic fertilizer application on both RYP soil and shallot crops, and then to connect the crop yield to the economic profit that might be possible gained by farmers. Therefore the objectives of this research are : 1) to explore the effect of oil palm empty bunch (OPEB) compost and goat manure on shallots cultivated on RYP soil, 2) to determine the best treatment combination as fertilization recommendation, and 3) to analyze the economic feasibility for organic shallot farms

MATERIALS AND METHODS

This research was conducted from June to November 2020 at the Experimental Field of the Faculty of Agriculture, Tentena Christian University, Pamona Village, Pamona Puselemba District, Poso Regency, at an altitude of 505 m above sea level. The soil in the experimental location is a type of red yellow podsolic soil (RYP) with an average pH ranging from 4.0-4.2 (acidic).

The experiment was arranged in a factorial randomized block design which consisted of two factors. The first factor was the dosage of OPEB compost, consisting of five types of treatment, namely 1 ton/ha, 2 ton/ha, 3 ton/ha, 4 ton/ha, and 5 ton/ha. The second factor was the dosage of goat manure with five types of treatments, namely 0.25 ton/ha, 0.50 ton/ha, 0.75 ton/ha, 1.00 ton/ha, and 1.25 ton/ha.

There were 25 plots of treatment combinations, where each treatment was replicated twice so that there were 50 experimental plot units overall. The experimental plot was 2 m x 1.5 m in size with a plant spacing of 20 cm x 30 cm. Organic fertilizer was applied to the soil a week before planting the seeds. The fertilizer was evenly mixed with the soil, then left for one week. Maintenance is carried out on plants, including watering, weed controlling, and pest and plant disease controlling. Shallot harvest was carried out when the crops were 60 days after planting.

There were three parameters observed. First, the soil pH was measured before the treatments were applied and at shallot's harvest time (after the treatment application). Second, the crop growth, including the measurements of the crop height (cm) at six weeks after planting (WAP) using a meter from the ground to the highest growing point, the number of crops leaves at 6 WAP, and the number of tillers in each cluster at 6 WAP. Third, the crop yield includes observing the number of tubers per cluster at harvest time, fresh tuber weight per plot (kg) at harvest time, and dry tuber weight per plot (kg) after drying in indirect sunlight one week later harvest.

Data on shallot farming included the yield and selling price of shallots, fixed costs (land tax, depreciation of agricultural tools and machinery, wages for workers in the family), and variable costs (wages for labor outside the family, cost of seeds, fertilizers, pesticides, and other means of production).

Data Analysis

The data collected were then analyzed using a two-way analysis of variance (two-way ANOVA) to determine the effect and significant interaction of OPEB compost dosage and goat manure on soil pH, growth, and yield of shallots. Tukey's Honest Significant Difference Test (Tukey's HSD) at the 0.05 level was carried out if there was a significant difference from the observed variables. Meanwhile, the analysis of shallot farming income was performed using the following equation:

$$\pi = TR - TC \qquad (1)$$

where π = income (Rp/year), TR = total revenue (Rp/year), and TC = total cost production (Rp/year). R/C Ratio analysis was done with the formula:

$$\frac{R}{C}\,\text{Ratio} = \frac{TR}{TC} \qquad (2)$$

R/C Ratio compares the total revenue gained by the farmer from the selling of shallot and the total production cost spent by the farmer. There are three criteria for the value of the R/C Ratio. Ratio value < 1 means that the farm experiences loss, ratio value = 1 means that the farm experiences break-even, and ratio value > 1 means that the farm gets profit. This study used two treatments that resulted in the highest shallot yield as the basis for farming income analysis. Those treatments were 5 ton/ha OPEB compost + 1.00 ton/ha goat manure and 5 ton/ha OPEFB compost + 1.25 ton/ha of goat manure.

The effectiveness of applying compost and manure was measured by calculating Relative Agronomic Relativeness (RAE) as supposed by Indriyati (2018) with modification. Minimum dosage was used as a control. The formula of RAE was then expressed as follows:

$$RAE = \frac{\frac{\text{shallot weight}}{\text{from tested treatment}} - \text{control}}{\frac{\text{shallot weight}}{\text{from standard fertiizing}} - \text{control}} \qquad (3)$$

We conducted Pearson correlation analysis to find out the significant correlation between the dosages of compost and manure and the yield of shallot's dry tuber. The correlation coefficient can be determined whether the correlation between the variables was strong or weak.

RESULTS AND DISCUSSIONS

Table 1 showed pH analysis of red yellow podzolic soil before treatment application, OPEB compost, and goat manure.

Table 1 showed no significant interaction

Table 1. The pH of red yellow podzolic soil before treatment application, oil palm empty bunch (OPEB) compost, and goat manure

Treatment	pH	Criteria
Red yellow podzolic soil	4.06	Acid
OPEB compost	8.00	Base
Goat manure	7.20	Neutral

Table 2. The effect of OPEB compost and goat manure dosages on soil pH, number of leaves, and number of tubers

OPEB compost dosage treatments (ton/ha)	Average soil pH	Goat manure dosage treatments (ton/ha)	Average soil pH
1	4.870 a	0.25	4.500 a
2	5.120 b	0.50	5.090 b
3	5.270 c	0.75	5.330 c
4	5.290 c	1.00	5.460 cd
5	5.370 c	1.25	5.540 d
Coefficient of Variance (%)	2.13		
OPEB compost dosage treatments (ton/ha)	The average of number of leaves (sheets)	Goat manure dosage treatments (ton/ha)	The average of number of leaves (sheets)
1	19.90 a	0.25	22.30 a
2	22.90 b	0.50	23.00 a
3	25.00 c	0.75	25.20 b
4	27.20 d	1.00	27.20 c
5	30.90 e	1.25	28.20 c
Variance Coefficient (%)	4.39		
OPEB compost dosage Treatments (ton/ha)	The average of number of tubers	Goat manure dosage treatments (ton/ha)	The average of number of tubers
1	4.50 a	0.25	5.20 a
2	4.90 ab	0.50	5.30 a
3	5.20 b	0.75	5.50 ab
4	6.50 c	1.00	6.10 bc
5	7.70 d	1.25	6.70 c
Coefficient of Variance (%)	8.51 %		

Remarks: Means followed by the same lowercase letters are not significantly different according to Tukey's HSD 5 %

effect between the dosage of OPEB compost and goat manure on the soil pH. However, the treatment of the two fertilizers independently affected the soil pH significantly. The increasing dosage of both fertilizers caused the degree of soil acidity to decrease and the pH value to increase.

As shown in Table 2, treatment of OPEB at 3 tons/ha resulted in the average soil pH of 5.270, which was not significantly different from the application at 4 and 5 tons/ha. Meanwhile, the manure dosage of 1.00 ton/ha treatment resulted in the average soil pH of 5.460, which was not significantly different from the application at 1.25 ton/ha. These values were higher than the soil pH values produced by fertilizer application at a lower dosage. It is indicated that the higher the fertilizer dosage increase the soil pH. Oil palm empty bunch compost and goat manure, which is alkaline and neutral, are effective enough in neutralizing the acidity of RYP soil. The compost has a pH that tends to be alkaline due to K_2O compounds. In the soil, those compounds react with H_2O and release OH^- ions that reduce the number of H^+ ions, decreasing soil acidity (Ramadhani et al., 2015). Asih et al., (2019) confirmed that the increase in soil pH of Ultisol type would be more significant if the OPEB compost were applied over ten years continuously.

In addition, goat manure has a neutral pH because it contains quite high K nutrients (Shofiah & Tyasmoro, 2018). Thus, the manure can increase soil pH due to the soil organic acid chelation process, in which the Al element that causes soil acidity can be reduced (Putra et al., 2015). The optimal pH range for plant growth is 5.6 to 6.0 (Prabowo & Subantoro, 2017), while for shallot crops, the optimal pH is 5.5 to 6.5 (Arman et al., 2016). If compared with the range of pH soil after treatment,

Table 3. The interaction effect of OPEB compost and goat manure on the crop height and number of tillers at the age of 6 WAP

Treatments	Shallot crop height (cm)					The average of compost treatments
OPEB compost dosages (ton/ha)	Goat manure dosages (ton/ha)					
	0.25	0.50	0.75	1.00	1.25	
1	22.35 a	22.65 a	23.00 bc	23.65 cd	24.10 e	23.15 a
2	22.75 ab	23.35 cd	24.25 ef	24.40 f	25.05 fg	23.96 ab
3	23.65 cd	24.85 f	24.00 cde	24.90 f	25.75 gh	24.63 b
4	24.50 f	26.25 h	25.85 h	27.75 hi	28.90 ij	26.69 c
5	25.60 g	26.85 h	28.10 i	31.75 j	30.50 j	28.56 d
The average of manure treatments	23.77 a	24.79 b	25,14 b	26.49 c	26.80 c	
Coefficient of Variance (%)	2.85					
Treatments	The number of shallot tillers					The average of compost treatments
OPEB compost dosages (ton/ha)	Goat manure dosages (ton/ha)					
	0.25	0.50	0.75	1.00	1.25	
1	3.0 a	3.0 a	3.0 a	4.0 ab	5.0 bc	3.60 a
2	4.0 ab	4.0 ab	4.0 ab	4.0 ab	5.0 bc	4.20 b
3	4.5 b	5.0 bc	5.0 bc	5.0 bc	5.5 cd	5.00 c
4	6.0 cd	5.0 bc	5.0 bc	6.0 cd	6.5 d	5.70 d
5	5.5 cd	6.0 cd	6.0 cd	8.0 e	8.0 e	6.70 e
The average of manure treatments	4.60 a	4.60 a	4.60 a	5.40 b	6.00 c	
Coefficient of Variance (%)	5.61					

Remarks: Means followed by the same lowercase letters are not significantly different according to Tukey's HSD 5%

which was between 4.5 and 5.5, the ideal pH value was achieved when using a manure dosage of 1.25 ton/ha. Due to the relatively short lifespan of the shallot crops (60 days), the observations at increasing soil pH were very limited.

There was a significant interaction effect of OPEB compost and goat manure on the height of shallot crops at the age of 6 WAP, as can be seen in Table 3. The interaction effect is a combined effect between the compost and manure, which simultaneously influences crop growth or yield.

Interaction effect of 4 ton/ha OPEB compost + 1.25 ton/ha goat manure resulted in the highest shallot height (Table 3). However, this result was not significantly different from the results of 5 ton/ha compost OPEB + 1.00 ton/ha of goat manure and 5 ton/ha of OPEB compost + 1.25 ton/ha of goat manure, as noted in Table 3. Thus, both fertilizers simultaneously improve crop growth by increasing crop height.

The increase in crop height is part of the vegetative crop growth. Nitrogen (N) is a nutrient that significantly affects vegetative growth. Goat manure, which is high in N nutrient content (can reach 1-2%) (Prasetyo, 2014), can be broken down quickly by soil microbial activity so that N nutrients can be available to plants (Afrilliana et al., 2017). Meanwhile, potassium (K) contained in OPEB compost plays a role in increasing the activity of enzymes in photosynthesis and respiration processes, thereby positively affecting the height increase in shallot crops. K nutrient also contributes to processing protein synthesis in accelerating the conversion of nitrates into protein. That process causes increasing the efficiency of N fertilization (Alfian et al., 2015). If it is related to the soil pH factor, the decrease in the acidity degree of RYP soil can reduce the fixation of K elements so that

Table 4. The interaction of OPEB compost and goat manure on fresh tuber weight at harvest and dry tuber

Treatments	Shallot fresh tuber weight (kg/plot)					The average of compost treatments
OPEB compost dosages (ton/ha)	Goat manure dosages (ton/ha)					
	0.25	0.50	0.75	1.00	1.25	
1	0.460 a	0.512 a	0.518 a	0.528 ac	0.652 bc	0.534 a
2	0.658 bc	0.668 bc	0.712 c	0.724 d	0.828 d	0.718 b
3	0.840 e	0.842 eh	0.884 fh	0.918 gh	0.970 hi	0.891 c
4	0.950 h	1.036 i	1.010 hi	1.042 i	1.086 i	1.025 d
5	1.048 i	1.010 hi	1.470 i	1.650 i	2.020 j	1.513 e
The average of manure treatments	0.791 a	0.887 b	0.919 bc	0.972 c	1.111 d	
Coefficient of Variance (%)	6.76					
Treatments	**Shallot dry tuber weight (kg/plot)**					**The average of compost treatments**
OPEB compost dosages (ton/ha)	Goat manure dosages (ton/ha)					
	0.25	0.50	0.75	1.00	1.25	
1	0.216 a	0.250 ab	0.278 bc	0.284 bc	0.384 d	0.282 a
2	0.352 bc	0.366 bc	0.376 cd	0.412 de	0.726 g	0.446 b
3	0.464 e	0.464 e	0.446 e	0.454 e	0.478 e	0.461 b
4	0.578 e	0.578 e	0.466 e	0.708 fg	0.593 ef	0.585 c
5	0.532 e	0.732 g	0.922 g	0.918 g	0.990 g	0.805 d
The average of manure treatments	0.428 a	0.478 ab	0.498 ab	0.555 bc	0.620 c	
Coefficient of Variance (%)	16.12					

Remarks: Means followed by the same lowercase letters are not significantly different according to Tukey's HSD 5%

the availability of K in the RYP soil will increase (Gunawan et al., 2019).

Table 2 indicated no significant interaction effect of OPEB compost and goat manure on the number of leaves of shallot crops. Both treatments also significantly affected the number of crop leaves independently. The application of OPEB compost at a 5 ton/ha dosage resulted in the most significant number of leaves of 30.90 at 6 WAP, compared to the other four dosages. Meanwhile, the most significant number of leaves resulting from the goat manure application was obtained at a 1.00 and 1.25 ton/ha dosage.

An increase in the dosage of OPEB compost and goat manure caused a significant increase in the number of leaves of shallot crops (Table 2). The N nutrient found in goat manure plays a direct role in synthesizing amino acids, proteins, nucleic acids, enzymes, nucleoproteins, and alkaloids needed in the vegetative growth of crops, in this case, the formation of leaves and increase in leaf green color. The addition of K in RYP soil through the application of OPEB compost can stimulate physiological processes in crops in the form of enzyme activity, protein synthesis, and cell enlargement (Suwandi et al., 2015). That process causes an increase in the number of leaves, and the formation of chlorophyll causes the color of the leaves to become greener.

The number of tillers at the age of 6 WAP, as demonstrated in Table 3, was significantly influenced by OPEB compost and goat manure treatments. There was also a significant interaction between both treatments on the number of tillers. The application of 1.00 and 1.25 ton/ha OPEB compost combined with 1.00 ton/ha of goat manure resulted in the largest number of tillers per cluster. Combining other treatments with a smaller fertilizer dosage resulted in fewer tillers. Simultane-

Table 5. Profit analysis of organic shallot farming

No.	Description	Value per hectare (IDR)	
		Fertilization treatment type 1	Fertilization treatment type 2
1.	Production (kg/ha)	3,060	3,300
2.	Selling price (Rp/kg)	35,000	35,000
3.	Total revenue	107,000,000	115,500,000
4.	Cost production:		
a.	Fixed cost		
	1) Land tax	100,000	100,000
	2) Depreciation of tools and machines	1,550,525	1,550,525
	Total fixed cost	1,650,525	1,650,525
b.	Variable cost		
	1) Seedlings	30,000,000	30,000,000
	2) OPEB compost	5,000,000	5,000,000
	3) Goat manure	4,000,000	5,000,000
	4) Pesticides	2,500,000	2,500,000
	5) Labors	24,500,000	24,500,000
	Total variable cost	66,000,000	67,000,000
c.	Total cost production	67,650,525	68,650,525
5.	Net profit	39,349,475	46,849,475
6.	R/C Ratio	2.719	2.465

ously, the use of OPEB compost and manure on RYP soil can increase the number of tillers formed in each cluster of shallot crops.

The data in Table 3 demonstrate that the increasing dosages of fertilizer applied to RYP soil encourage the formation of more tillers per cluster. If it is related to the growth of crop leaves, the more leaves that are formed, the more tillers will be produced. The greater number of leaves and amount of photosynthate improved the growth, development of crops, and storage of food reserves. According to Purba (2016), photosynthesis is distributed from leaves to all plant parts, especially meristem tissue at growing points and tubers that are starting to develop. The photosynthate accumulation in the tubers causes the tubers to form tillers, rising to form clusters of shallot bulbs.

Table 2 showed that the application of OPEB compost and goat manure significantly affected the number of shallot tubers at harvest. However, there was no significant interaction effect on the number of shallot tubers per cluster. The application of OPEB at 5 tons/ha produced the largest number of tubers (7.70 tubers per cluster). Meanwhile, the goat manure application at a 1.00 ton/ha dosage was not significantly different from the application of 1.25 ton/ha. The interaction effect was not observed, which is assumed to be due to the development of each nutrient in each type of fertilizer that is stronger than when the nutrients work simultaneously, particularly when the crops enter the generative phase.

In general, it can be seen that the increasing dosages of fertilizer on RYP soil cause the number of shallot tillers to increase, in which more tillers will increase the number of tubers per cluster of shallot crops. Afrilliana et al., (2017) stated that the number of lateral shoots in the seedlings would determine the number of tubers formed, where calyx that changed function would form new tubers, which when enlarged would produce shallot-coated tubers. Furthermore, Afriliana et al., (2017) confirmed that crop genetic factors influenced the number of tillers and the number of shallot tubers. Still, the inherited properties could be affected by external factors, including the addition of nutrients to the soil as the planting medium.

Alfian et al., (2015) argued that the number of tubers formed in shallot crops was influenced by the crop variety and availability of nutrients, in

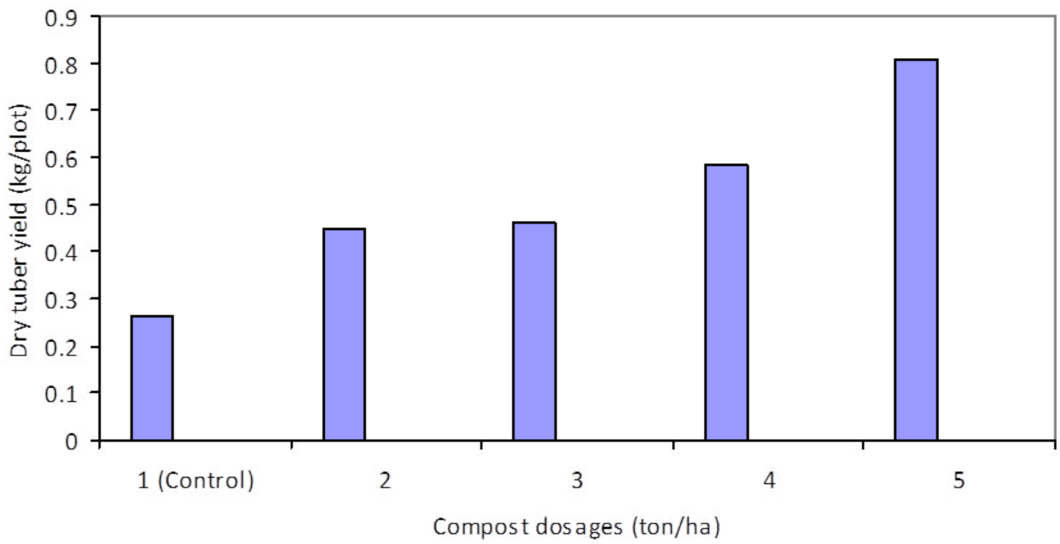

Figure 1. The relationship between compost dosages and shallot's yields

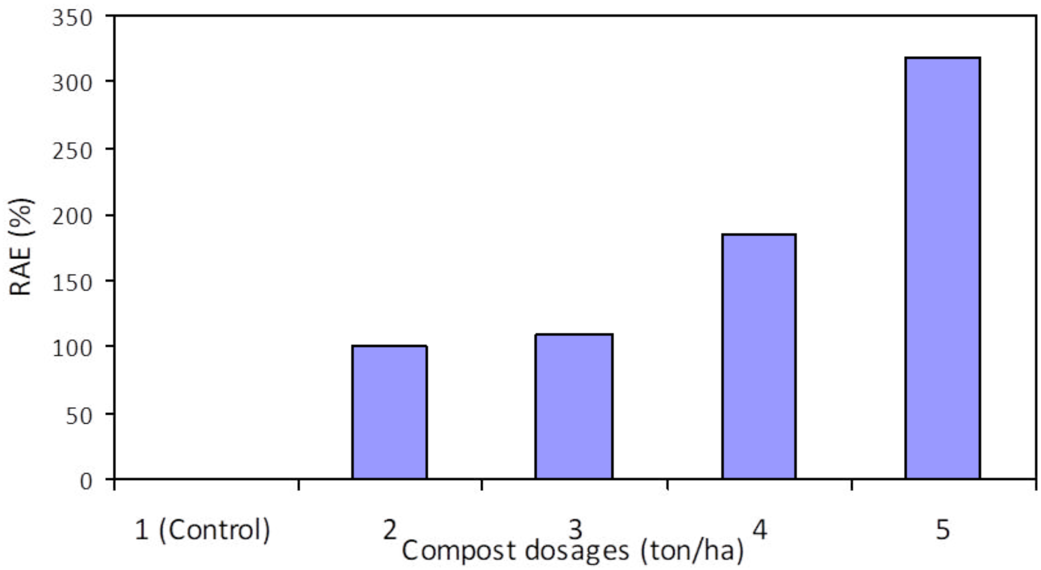

Figure 2. The RAE value of compost application on shallot's yields

this case, the K element. Crops use K nutrients to synthesize amino acids and proteins from ammonium ions. In addition, the K element also serves in increasing the metabolic process of crops in the forms of cell enlargement and the transportation of photosynthetic products (assimilates) from the leaves through the phloem (filter vessels) as a transport network to the reproductive organ tissues, that is, shallot tubers. The greater the accumulation of assimilates in the tubers will encourage the formation of an increasing number of tubers. The tubers that are formed in shallot crops are the result of calyx inflating. Thus, there is a close relationship between the number of tubers formed and the number of shallot leaves (Hidayat et al., 2010).

Table 4 showed that the weight of fresh shallot tubers at harvest time was significantly influenced by the application of OPEB compost and goat

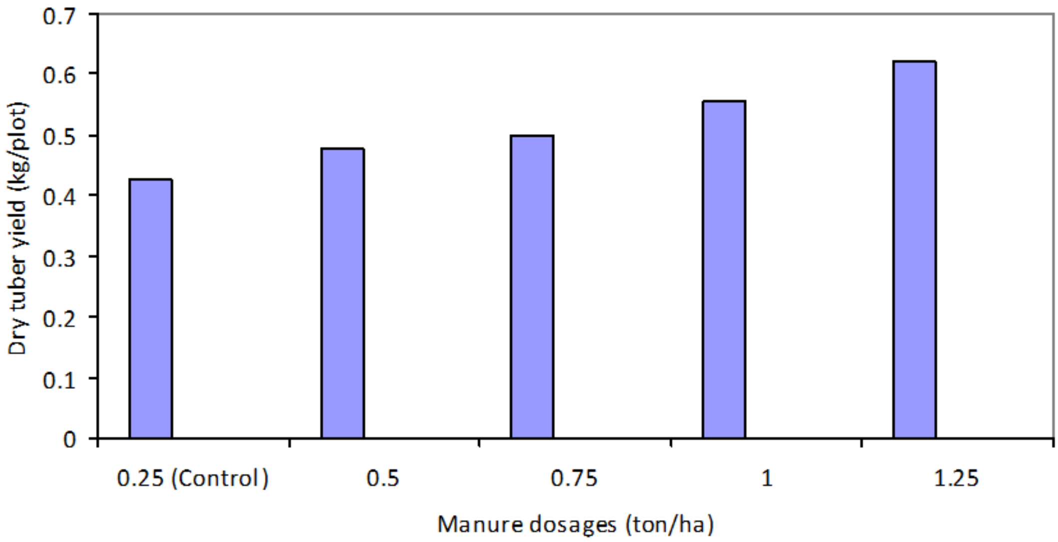

Figure 3. The relationship between manure dosages and shallot's yields

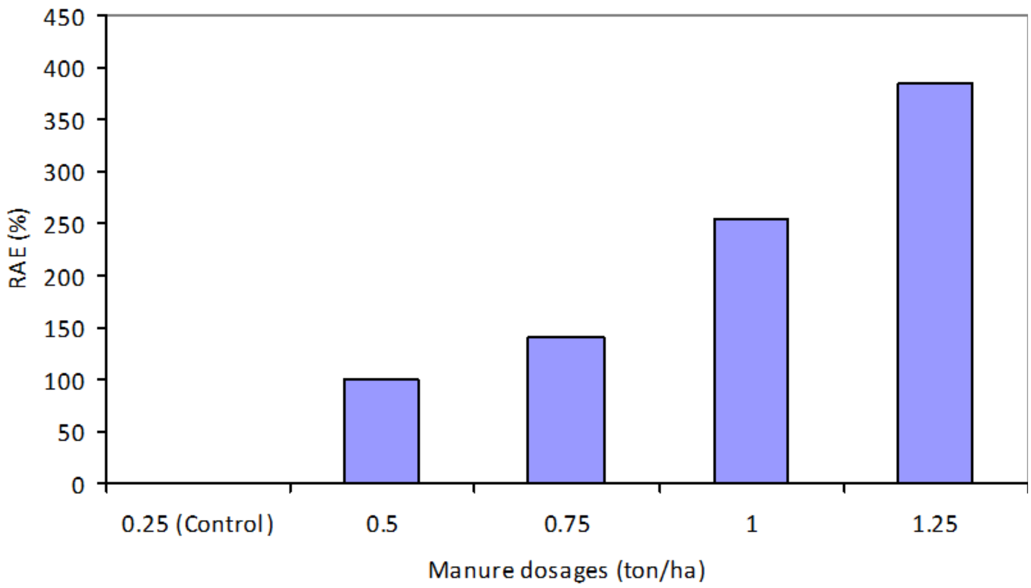

Figure 4. The RAE value of manure application on shallot's yields

manure. Both treatments also generated a significant interaction effect on fresh tuber weight. The combination of 5 ton/ha of OPEB compost + 1.25 ton/ha of goat manure resulted in the highest fresh tuber weight (2.020 kg/plot).

A study by Napitupulu & Winarto (2010) indicated an interaction effect of N and K fertilizers on the fresh tuber weight of shallot crops. This simultaneous effect points out a balance of nutrients in the RYP soil needed for crop growth. N nutrient in goat manure improves crop vegetative growth, encouraging a better generative phase. Meanwhile, the presence of K nutrient in RYP soil plays a very important role in synthesizing carbohydrates and protein, which leads to tuber size enlargement and increases fresh tuber weight. Goat manure also contains 0.8% phosphorus (P) (Prasetyo, 2014), where crops use P elements to form cell nuclei, to help the process of cell division, and to increase the number of cells, as well as to serve as a regulator of photosynthate distribution between sources and reproductive organs (Arman et al., 2016). P element in the RYP soil also functions in shallot tubers' enlargement and weight gain.

The application of OPEB compost and goat manure significantly affected the weight of dry tubers of shallot crops, as pointed out in Table 4. Both treatments also have a significant interaction effect on the weight of shallots dried for one week after harvest. The combination of 4 ton/ha OPEB compost + 1.00 ton/ha of goat manure was not significantly different from the results of several treatment combinations with higher dosages, such as the combination of 5 ton/ha OPEB compost + 0.50 ton/ha goat manure, the combination of 5 ton/ha OPEB compost + 0.75 ton/ha goat manure, the combination of 5 ton/ha OPEB compost + 1.00 ton/ha goat manure, and the combination of 5 ton/ha OPEB compost + 1.25 ton/ha goat manure.

The yields of dry tubers from the treatment combinations considered optimal could exceed the production in the level of farmers around the research location as many as 0.76 tons/ha. However, this productivity value is still below the average shallot production in Central Sulawesi, reaching 5.31 tons/ha (Sulteng, 2017). The factor that is assumed to have contributed to this difference in productivity is the tenuous spacing used for planting, namely 20 cm x 30 cm (Table 4). Alfian et al., (2015) indicated that a denser spacing such as 10 cm x 10 cm would lead to a lower soil evaporation rate and reduce the risk of nutrient loss. Thus, nutrients will be optimally available to meet the needs of crops.

Farming economic analysis was carried out to determine the net profit from shallot farming, which applies OPEB compost organic fertilizer and fermented goat manure on RYP soil. This analysis was designed for shallot farming on a 1-hectare scale using a combination of fertilizer treatment of 5 ton/ha OPEB compost + 1.00 ton/ha goat manure as fertilization treatment type 1 and the combination of 5 ton/ha OPEFB compost + 1.25 ton/ha of goat manure as fertilization treatment type 2 (Table 5). This analysis model assumes that farmers only use organic fertilizers as an alternative to the use of chemicals, including synthetic chemical fertilizers on soil and crops (Vebriyanti et al., 2018). The analysis results in the form of profit calculations and the R/C value of organic shallot farming are shown in Table 9.

The calculation results in Table 9 show that organic shallot farming provides a net profit of IDR 39,349,475/ha (fertilizer treatment type 1) and IDR 46,849,475/ha (fertilizer treatment type 2). The R/C ratio values, respectively 2.719 and 2.465, mean that farming is economically feasible because every 1-unit cost will provide more than two revenue units. The value of R/C Ratio in fertilization treatment type 1 is greater than the R/C ratio in treatment type 2 because the total production cost incurred is smaller, especially for fertilization expense. Thus, although the profit obtained in fertilization type 1 is less, the R/C Ratio value is greater than that of type 2.

Relative Agronomic Effectiveness (RAE) analysis to determine the effectiveness of organic fertilizer application was conducted on the shallot's dry tuber. According to Table 8, the application of compost dosages of 2, 3, 4, and 5 ton/ha resulted in a significantly different yield of shallot's dry tuber compared to the application of a minimum compost dosage of 1 ton/ha. The results of the RAE analysis point out that the effectiveness of organic compost in increasing the yield of shallot's dry tubers ranges from 100% to 318.90%. According to correlation analysis, the Pearson correlation coefficient was 0.964 with a significance of 0.008. The correlation coefficient was significant at a confidence level of 0.95 means there was a very strong correlation between compost dosages and shallots' dry tuber yield.

The Relative Agronomic Effectiveness (RAE) value effectively measures a fertilization treatment application compared to the fertilization standard measure (Indriyati, 2018). The results show that the effectiveness of organic fertilization increases when the fertilizer dosage is also increased. In fertilization using compost, the highest RAE value of 318.90% was obtained at the 5 ton/ha compost dosage. Compared with the standard treatment with an RAE value of 100%, there was an increase in the effectiveness of 218.90%. The more effective fertilization will eventually lead to an increase in crop yields. The yield of shallot's dry tubers at compost dosage of 1 ton/ha was 0.282 kg/plot (0.94 ton/ha), while the yield at the compost dosage of 5 ton/ha was 0.805 kg/plot (2.68 ton/ha), indicating an increase in the yield of dry tubers of 185.46%.

The application of goat manure with the highest dosage of 1.25 ton/ha also gave the highest dry tuber yields (0.620 kg/plot), which was not significantly different from the results of compost dosage of 1.00 ton/ha (Table 8). However, the results of RAE analysis indicated that manure application was able to incline the yield of dry tubers, which was greater than the compost application, which was between 100% and 384%.

The RAE value in manure application also points out an increase along with fertilizer dosage. The highest RAE value was obtained at the dosage of 1.25 ton/ha manure, 384%, showing an effectiveness increase of 284% compared to standard treatment with an RAE value of 100%. The yield of dry tubers at the dosage of 0.25 ton/ha manure was 0.428 kg/plot (1.43 ton/ha), while the dry tuber yields at the dosage of 1.25 ton/ha manure were 0.620 kg/plot (2.07 ton/ha), indicating a yield enhancement of 44.86%. Thus, an increase in the effectiveness of manure will cause addition in the yield of dry tubers. Correlation analysis suggested that the value of the Pearson correlation coefficient was 0.986. The significance of the correlation was 0.002, which was significant at a confidence level of 0.95. A very strong correlation was then indicated between manure dosages and the yield of dry tubers.

The application of organic compost and manure effectively improved soil fertility by enhancing the amount of soil organic matter in organic C, reducing the acidity of red yellow podzolic soil, and increasing soil microbial activities. The improvement of soil fertility causes improvements in crop growth processes, where root growth takes place optimally to facilitate the absorption of nutrients from the soil. Adequate absorption of nutrients will ultimately increase crop yields (Indriyati, 2018).

CONCLUSION

The combination of 5 ton/ha of compost and 1.25 ton/ha of goat manure yielded the highest dry tuber production of 0.990 kg/ plot (3.30 ton/ha). Organic shallot farming on RYP soil provides profit with an R/C Ratio > 1, so the farming is economically feasible. The highest effectiveness of compost application was obtained at the dosage of 5 tons/ha. While the highest effectiveness of manure application at the dosage of 1.25 tons/ha. A very strong correlation is found between the organic fertilizers and shallot's dry tuber yield.

ACKNOWLEDGEMENTS

Gratitude and appreciation are expressed to the Directorate of Research and Community Service (Direktorat Riset dan Pengabdian Masyarakat/ DRPM), Indonesian Ministry of Research and Technology–National Research and Innovation Agency (Kementerian Riset dan Teknologi RI-Badan Riset dan Inovasi Nasional/Kemristek-BRIN) for funding this research through the scheme of Beginner Lecturer Research (Penelitian Dosen Pemula/PDP) in the year of 2020.

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The Addition of *Trichoderma* sp. in Various Types of Organic Liquid Fertilizer to Increase NPK Nutrient Uptake and Soybean Production in Ultisol

DOI: 10.18196/pt.v10i1.9814

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ABSTRACT

Indonesia imports up to 70% of its domestic soybean needs from abroad. Therefore, it is necessary to increase soybean yields in Indonesia, among others, by providing Liquid Organic Fertilizer (LOF). The purpose of this study was to determine the effects of LOF enriched with *Trichoderma* sp. on the yield of Mutiara-1 soybean in Ultisol. The experiment was conducted on dry land with a pH of 4.66 (acidic) in Kuranji Village, Kuranji District, Padang. The experiment was arranged in a factorial completely randomized design consisting of two factors, including the dose of Trichoderma sp. and the type of LOF. The doses of Trichoderma sp. inoculants were 0, 1, and 2 kg for every 20 kg of fermented LOF main ingredients. The main ingredients of LOF used in this experiment were *Chromolaena odorata*, *Tithonia diversifolia*, and *Trichoderma* sp. Meanwhile, the type of LOF tested was according to the composition of the main ingredients, consisting of no LOF, Crocober, and Tithocroco. The data obtained were analyzed using ANOVA and continued with the LSD test at a 5% significance level. The results showed that the addition of 2 kg of Trichoderma sp. inoculants to Tithonia + *C. odorata* (Tithocroco) resulted in the highest dry seed production, reaching 3.17 tons ha-1 or an increase of 38.42% compared to those without LOF.

Keywords: *Chromolaena odorata*, Liquid Organic Fertilizer, Soybean, *Tithonia diversifolia*, *Trichoderma* sp.

ABSTRAK

Indonesia mengimpor hingga 70% kebutuhan kedelai domestiknya dari luar negeri. Oleh sebab itu perlu upaya meningkatkan hasil kedelai di Indonesia antara lain dengan pemberian Pupuk Organik Cair (POC). Tujuan penelitian adalah untuk mengetahui peranan dari POC yang diperkaya dengan Trichoderma sp terhadap hasil kedelai Mutiara-1 pada Ultisol.Percobaan telah dilakukan di lahan kering dengan pH 4,66 (masam) di Kelurahan Kuranji, Kecamatan Kuranji Kota Padang. Percobaan menggunakan berbagai jenis bahan utama dijadikan POC antara lain; Chromolaena odorata, Tithonia diversifolia dan Trichoderma sp. Percobaan dirancang dengan rancangan acak lengkap faktorial dengan 2 faktor perlakuan, yaknidosis Trichoderma sp. dan jenis POC. Dosis inokulan Trichoderma sp., terdiri dari 0, 1 dan 2 kg untuk setiap 20 kg bahan utama POC yang difermentasikan. Jenis POC yang diuji didasarkan pada komposisi bahan utama terdiri dari tanpa POC, Crocober dan Tithocroco. Data yang diperoleh dianalisis menggunakan ANOVA pada taraf nyata 5% dan dilanjutkan dengan uji LSD taraf nyata 5%. Dari hasil percobaan maka dapat disimpulkan bahwa pemberian 2 kg inokulan Trichoderma sp pada POC Tithonia + C.odorata (Tithocroco) menghasilkan produksi biji kering tertinggi mencapai 3,17 ton ha^{-1} atau meningkat 38,42% dibandingkan dengan yang tidak diberi POC.

Kata Kunci: *Chromolaena odorata, Pupuk Organik Cair, Kedelai, Tithonia diversifolia, Trichoderma sp.*

INTRODUCTION

Trichoderma sp. is a saprophytic fungus important in the plant nutrient cycle. This fungus is involved in the transaction of nutrients in nature. *Trichoderma* sp. is commonly used in making organic compost, especially from rice straw. Fermentation of rice straw using *Trichoderma* sp. has a positive impact on increasing the nutrient content of compost and fertilizing the soil. The use of *Trichoderma* sp. has also been developed as a biological agent in increasing plant resistance to disease caused by soil-borne fungi and others (de Oliveira et al., 2014; Chamzurni et al., 2011). *Trichoderma* sp. is believed to be able to accelerate the decomposition of organic matter in nature so that it can shorten the fermentation time, which is quite long. *Trichoderma* is green in color with

Article History
Received: 14 Sep 2020
Accepted: 18 Sep 2021

a slightly tart and sweet aroma. Usually, people breed it using rice or rice and bran media. The culture media must contain carbohydrates so that the fungus can live to meet the food from these carbohydrates.

The use of LOF using *Trichoderma* sp. has been reported by Putri& Jamilah (2018).Rizal & Susanti (2018) have also reported increased food crop yields using these fungi as decomposers. The manufacture of liquid organic fertilizer (LOF), which is used by spraying it over the entire surface of the plant evenly and periodically, has been reported by Jamilah et al.(2015).The popular liquid organic fertilizer comes from shrubs and agricultural waste. Besides cleaning the environment, it also plays a role in inserting these materials into the food chain in nature. The use of *Chromolaena odorata* as LOF (Crocober plus and Unitas Super) has been successful in various crops of rice, corn, soybeans, vegetables, and fruits (Jamilah & Permana, 2015; Jamilah, Fadhila, & Mulyani, 2017). However, aside from *C. odorata*, many other shrubs can be used as the main ingredients for LOF, including *Tithonia diversifolia*. This plant has been reported to increase the yield of upland rice by 13.33% (Jamilah & Juniarti, 2015). *T. diversifolia* has a high content of N and K, so it can be used as material for making fertilizers. The advantages of these two types of shrubs are that they are resistant to pruning and quickly recover their growth, and they are easy to produce large clumps.

Tithonia as the main ingredient of LOF, which increased 13.33% of paddy field rice, has been reported by Jamilah, Maradona, Zahanis, & Ernita (2014).The combination of *C. odorata* and Tithonia is suitable for manufacturing LOF equipped with *Trichoderma* sp. There is no information on the effectiveness of all these ingredients on food crops. Therefore, the manufacture of LOF is necessary. In addition to reducing the purchase of artificial fertilizers, LOF also overcomes the shortage of nutrients in plants. Liquid organic fertilizer contains macro and micronutrients, so it is very suitable as a complementary fertilizer with expensive artificial fertilizers.

Soybean yields in Sumatra are significantly low, with an average of only 1.25 tons ha^{-1} compared to production in Java, which can reach 1.6 tons ha^{-1}(BPS, 2021). Soybean production in the United States is 34 bushels per acre or equivalent to 2.13 tons ha^{-1} (Brumm, 2003), making them an exporter of soybeans, including to Indonesia. The problem of low soybean yields in Indonesia is caused by, among others, low soil fertility (especially Ultisols), limited availability of artificial fertilizers, and many pests and diseases. It should be noted that the demand for soybeans in Indonesia is very high. Indonesia imports 70% of its domestic soybean needs (Satria, 2015). The use of superior varieties such as Mutiara-1 (BATAN, 1998)is very beneficial because of the large grain size and high yield per hectare (3.5 tons ha^{-1}). Therefore, applying LOF to soybean cultivation in West Sumatra is necessary. The purpose of this study was to determine the effects of LOF enriched with *Trichoderma* sp. on the levels of N, P, K and yield of Mutiara-1 soybean in Ultisol.

MATERIALS AND METHODS

The experiment was conducted on dry land with a pH of 4.66 (acidic) in Kuranji Village, Kuranji District, Padang.This experiment used various main ingredients to manufacture liquid organic fertilizer (LOC), including *C. odorata*, *T. diversifolia*, manure, coconut fiber, local microorganisms, and *Trichoderma* sp. The experiment was arranged in a factorial, completely randomized design, consisting of two factors. The first factor was the doses of *Trichoderma* sp. inoculants, which were 0, 1, and 2 kg for every 20 kg of the fermented main ingredients of the LOF. The second factor was the type of LOF based on the composition of the main ingredients, consisting of no LOF, Crocober (*C. odorata* + Coconut Coir + Manure + MOL), and Tithocroco (*T. diversifolia* + *C. odorata* + Coconut husk + Manure + MOL). The data obtained were analyzed using ANOVA with a significance level of 5%. The data showing significant differences between treatments were tested using LSD with a significance level of 5% (Steel & Torrie, 1980). The observations were made on plant N, P, and K levels, the weight of 100 seeds, number of pods per plant, pithy pods, and dry seed weight per plot and per hectare. P analysis was performed using the wet ashing method with H2SO4 and H2O2, then the extract was read on a spectronic device, and K was determined using the AAS tool (Eviati & Sulaeman, 2009).

LOF was prepared based on the same ratio except for local microorganisms (MOL). The compositions of the ingredients were Crocober (*C. odorata* + Coconut Coir + Manure + MOL) and Tithocroco (*T. diversifolia* + *C. odorata* + Coconut husk + Manure + MOL) (Jamilah & Novita, 2016) (Jamilah& Ben, 2018). All the determined main ingredients were finely chopped, stirred, and fermented for two weeks in a humid atmosphere by covering them tightly. Local microorganisms were made by crushing papaya fruit waste into old coconut water fermented using sugar for two weeks. The fermented main ingredient of LOF was added with 1 kg or 2 kg of *Trichoderma* sp. in 20 kg of mixed ingredients as the forerunner to LOF. Groundwater was then added, with a ratio to LOF of 1:1. The fertilizer was fermented again for two weeks in a tightly closed container. LOF was harvested after the aroma disappeared, which was indicated by the darkened color.

Soybean seeds were planted two seeds in each planting hole with a spacing of 20 x 25 cm on a plot measuring 2 x 2 m. The soil was pulverized, and two weeks before planting, liming using dolomite equal to 1 x Aldd was carried out. The basic fertilizers given were 50 kg Urea, 100 kg SP36, and 100 kg KCl per hectare, which were applied ten days after planting. The LOF was applied on soybean plants by taking every 50 ml of LOF solution dissolved in 1 liter of water and sprayed evenly and smoothly over the plant shoots. LOF application was carried out every other week and stopped when the plants started filling pods. From the results of this activity, LOF was applied to plants only three times.

Pest and weed were difficult to control because the intensity of the rain was too high. Plants (two clumps/plots) were destroyed 43 days after planting to determine plant N, P, and K levels and shoot dry weight. The remaining plants were kept until harvest. Crops are ready to harvest when the pods become yellowish and hard.

RESULTS AND DISCUSSION

The NPK levels were determined at the end of the vegetative growth phase (Figure 1). The NPK levels in soybean plants during the lower primordia phase were generally more influenced by the type of LOF than by *Trichoderma* sp. or the combination of both. The impact of *Trichoderma* sp. was not significantly able to increase the P and K levels, but there was an effect on the N levels of plants.

The N, P, and K levels were higher in the plants treated with Crocober. Meanwhile, the lowest level of N was observed in the plants without LOF application. The impact of LOF on the P and K levels was not significantly different. Plants absorb N, P, K, and other elements. However, the N, P, and K elements are classified as macro elements needed by plants. Nutrient levels of these plants will then affect the growth and yield of soybean plants. Compared to the P and K content of soybeans cultivated

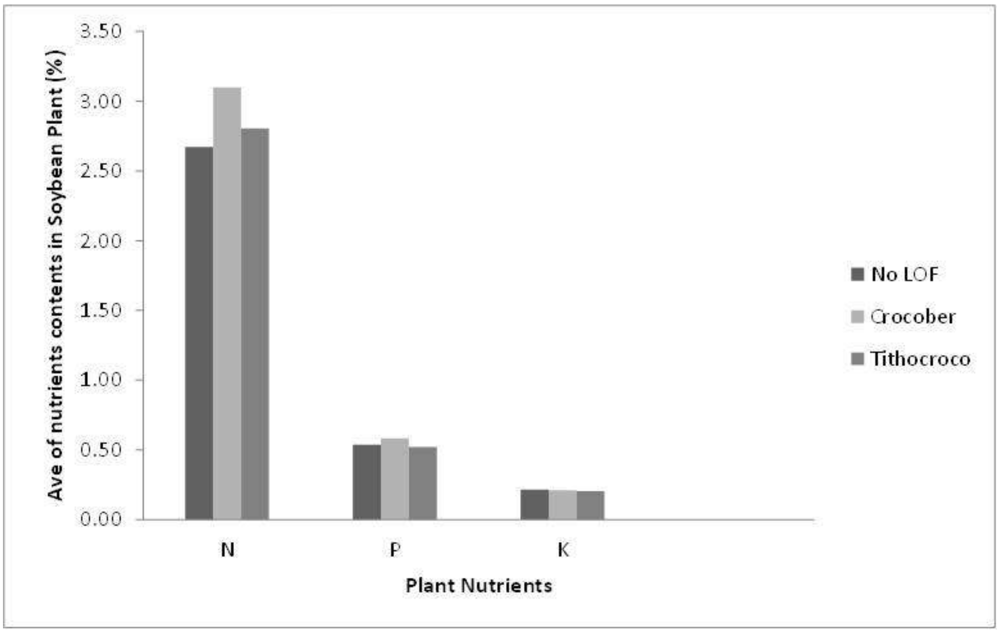

Figure 1. NPK levels in soybean plants at 43 days after planting

in Lampung, the P level in soybeans was higher in West Sumatra, but the mean level of K (<0.5%) was much lower than in Lampung (0.6-0.8%) (Wijanarko & Taufiq, 2004). Plants with sufficient N, P, and K nutrients will produce optimal metabolic activity. N is important in increasing the amount of leaf chlorophyll so that the N assimilation activity is optimal, producing high organic matter.

There was an interaction effect of LOF and *Trichoderma* sp. on the plant N level and shoot dry weight at 43 days after planting (Table 3). In general, the addition of 1 kg of *Trichoderma* sp. inoculants for every 20 kg of LOF main ingredients was able to increase 1% of plant N levels. However, if the dose of *Trichoderma* sp. inoculant increased again, plant N levels did not increase. The application of Crocober was able to increase plant N level compared to Tithocroco.

The addition of *Trichoderma* sp. significantly increases the effectiveness of LOF in improving plant growth. This is because *Trichoderma* sp. can produce hydrolysis enzymes, glucanase, proteases, and chitinase (Gómez, Chet, & Herrera-Estrella, 1997). The enzyme will accelerate the decomposition of organic matter contained in the LOF so that it is easy to mineralize, releasing ions such as NO_3^{-1}, K^+, and HPO_4^{2-}. Plants can immediately absorb these ions. Nutrients maximally absorbed by plants during the growth phase will increase the number of soybean pods. Even if given 2 kg of *Trichoderma* sp. inoculants, Tithocroco could produce the highest number of pods compared to other treatments.

Table 1 shows the interaction effect of *Trichoderma* sp. and LOF on N level and dry weight of plant crown per clump. N level was influenced more by the interaction of LOF and *Trichoderma* sp., as explained above. Crocober was superior in producing the highest N levels in plants, either with or without the addition of *Trichoderma* sp. The high nutrient content in the plant material will be translocated to the storage section or seeds during the seed filling phase. Photosynthate produced by the green part of the plant will be translocated into storage media, either in seeds, stem, roots, or leaves as sinks (Oosterhuis, 2009; Setiawan, Rosadi, & Kadir, 2014; Tanah & Penelitian, 2005; Tan, 2013).

Plants treated with the addition of 2 kg of *Tricho-*

Table 1. The results of the interaction test of Trichoderma sp. and LOF on N levels and shoot dry weight of soybean plants per clump

Type of LOF	Application of Trichoderma sp. (kg/20 kg of the LOF's main ingredient) inoculants					
	N level (%)			Shoot dry weight per clump (g)		
	0	1	2	0	1	2
Without LOF	1.96 Bc	3.22 Aa	2.84 Ab	13.00 Ab	18.22 Aa	14.56 Bb
Crocober	3.33 Aa	3.07 Aab	2.91 Ab	14.14 Aa	14.36 Ba	17.15 Aa
Tithocroco	2.98 Aa	3.12 Aa	2.32 Bb	12.15 Ab	17.25 ABa	19.51 Aa

Remarks: Means followed by the same letters in the same column are not significantly different according to LSD test at 5%.

Table 2. Effects of the doses of Trichoderma sp.for every 20 kg of LOF main ingredients on the number of pods

Doses of Trichoderma sp.(kg/20 kg LOF main ingredients)	Number of pods per clump
0	32.81 B
1	33.82 B
2	37.48 A

Remarks: Means followed by the same letters in the same column are not significantly different according to LSD test at 5%.

Table 3. Effects of LOF on the number of filled pods and weight of 100 seeds

Type of LOF	Number of filled pods (%)	Weight of 100 seeds (g)
Without LOF	83.14 A	22.31 A
Crocober	82.69 AB	21.64 A
Tithocroco	79.19 B	20.88 A

Remarks: Means followed by the same letters in the same column are not significantly different according to LSD test at 5%.

Table 4. Effects of the addition of Trichoderma sp. to LOF on the weight of dry seeds at a moisture content of 14%

Type of LOF	Application of Trichoderma sp. (kg/20 kg of the LOF's main ingredient) inoculants					
	Weight of dry seeds at a moisture content of 14% (g plot-1)			Weight of dry seeds at a moisture content of 14% (ton ha-1)		
	0	1	2	0	1	2
Without LOF	919.88Aab	912.92Ab	1082.31Ba	2.29	2.28	2.70
Crocober	967.38Aa	1009.84Aa	946.13Ba	2.42	2.52	2.36
Tithocroco	925.03Ab	912.94Ab	1268.88Aa	2.31	2.28	3.17

Remarks: Means followed by the same letters in the same column are not significantly different according to LSD test at 5%.

derma sp. for every 20 kg of LOF main ingredients produced a higher number of pods (Table 2). The higher doses of *Trichoderma* given will increase the number of pods per clump. There was no significant effect of LOF on the number of soybean pods per clump, but a significant effect on rice pods was observed. This proves that LOF is a nutrient needed by plants for filling their pods.

The number of filled pods and the weight of 100 seeds were not affected by the application of LOF and *Trichoderma* sp. (Table 3). The weight of 100 seeds was not affected by fertilization but was more determined by plant genetics.Based on BATAN (1998) and Riniarsi (2015),the weight of 100 seeds of soybean cv. Mutiara-1 reached 23.2 g, much larger than that of other varieties, which were only around 8.36 g for the Tanggamus and Sibayak varieties (Wijanarko & Taufiq, 2004). The weight of 100 seeds in this study did not match the description of the Mutiara-1 variety, which is likely because the nutrients received by soybean plants are still not optimal because the weight of 100 seeds has the potential to be increased again.

There was an interaction effect of LOF and inoculants on the weight of dry seeds at a moisture content of 14%. The highest dry seed production was observed in the plants treated with the addition of 2 kg of *Trichoderma* sp. inoculants in every 20 kg of Tithocroco (Table 4). All types of LOC without *Trichoderma* sp. resulted in the lowest dry seed production. This result shows that adding *Trichoderma* sp. to the LOF is important. Its impact has been proven on the uptake of N, P, and K nutrients, which subsequently affect the vegetative growth and ultimately increase the production of dry seeds.

In general, the addition of *Trichoderma* sp. to all LOF treatments gave high seed yields. The addition of 2 kg of Trichoderma/20 kg of the main ingredient of Tithocroco was able to produce the highest seed weight, reaching 3.17 tons ha^{-1}. Plants only given *Trichoderma* sp. produced the lowest dry seed weight. However, the combination treatment of 2 kg of *Trichoderma* sp. inoculants with 20 kg of Tithocroco produced the highest dry seed weight, reaching 3.17 tons ha^{-1}, which was increased by 38.42% compared to plants without LOF and *Trichoderma* sp.

CONCLUSION

From the experimental results, it can be concluded that the addition of 2 kg of *Trichoderma* sp. inoculants in every 20 kg of Tithocroco resulted in the highest dry seed production, reaching 3.17 tons ha^{-1}, increased by 38.42% compared to those not given with LOF.

ACKNOWLEDGEMENT

The authors would like to thank the Ministry of Education and culture for funding the research under contract no. 092/LL.10/PG/2020, March 11, 2020. Gratitudes are also expressed to the Rector of the University of Tamansiswa Padang for supporting this research as well as the head of LPPM and the Dean of the Faculty of Agriculture Universitas Padang for facilitating this research.

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Determination of Agronomic Characteristics as Selection Criteria in Potato Crossing Lines

DOI: 10.18196/pt.v10i1.7571

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ABSTRACT

Vegetative propagation of potato decreases variation in commercially cultivated varieties. Induction of variability in potatoes is needed for crop improvement. Selection is selecting the best individual plants based on the desired characteristics, which will be effective when suitable characteristics are used. The objective of this study was to determine the agronomic characteristics for the selection of potato crossing lines through heritability, genetic variability, and genotypic correlation. The experiment was conducted at the Greenhouse, Sumber Brantas Village, Batu City, East Java. The materials used were 30 potato lines resulting from LJPRSD1 x AP-4. This study was arranged in a complete randomized design (RCD) with three replications. The agronomic characteristics observed include plant height, stem diameter, number of leaves, the diameter of tuber, number of tubers, tuber length, weight per tuber, starch, and glucose. Almost all characteristics observed showed high heritability values, except stem diameter and tuber length. The genetic variability in stem diameter, tuber diameter, and tuber length was low, whereas the genetic variability in other characteristics was slightly low. The genotypic correlation was significant between characteristics, except between starch content and weight per tuber. Meanwhile, the agronomic characteristics used for selection are plant height, diameter of tuber, number of tubers.

Keywords: Agronomic characteristics, Genetic variability, Genotypic correlation, Heritability

ABSTRAK

Perbanyakan kentang secara vegetatif menyebabkan variasi varietas kentang komersial kurang berkembang. Induksi variabilitas pada kentang sangat dibutuhkan untuk perbaikan tanaman. Seleksi adalah kegiatan memilih individu terbaik berdasarkan sifat tanaman yang diinginkan. Jika karakter seleksi yang digunakan tepat, kegiatan seleksi menjadi sangat efektif. Tujuan dari penelitian ini adalah menentukan karakter agronomis yang tepat, dan digunakan dalam pemilihan karakter populasi galur kentang silang melalui heritabilitas, keragaman genetik, serta korelasi genotip. Percobaan dilakukan di Rumah Kaca, Desa Sumber Brantas, Kota Batu, Jawa Timur. Bahan yang digunakan adalah 30 galur kentang sebagai hasil persilangan varietas LJPRSD1 x AP-4. Rancangan percobaan yang digunakan adalah Rancangan Kelompok Lengkap Teracak (RKLT) dengan 3 ulangan. Karakter agronomi yang diamati adalah tinggi tanaman, diameter batang, jumlah daun, diameter umbi, jumlah umbi, panjang umbi, berat per umbi, kadar pati, dan glukosa. Hasil heritabilitas pada hampir semua karakter memiliki nilai tinggi, kecuali untuk diameter batang dan panjang umbi. Keragaman genetik pada diameter batang, diameter umbi, panjang umbi rendah, sedangkan karakter lain agak-rendah. Korelasi genotip signifikan antara karakter, kecuali kadar pati dan bobot per umbi. Karakter agronomi yang dapat digunakan untuk seleksi adalah tinggi tanaman, diameter umbi, dan jumlah umbi.

Kata kunci: Heritabilitas, Karakter agronomi, Keragaman genetik, Korelasi genotip

INTRODUCTION

Potato (*Solanum tuberosum*) is an economically important crop in Indonesia, as shown by its increasing yearly demand (Statistik Konsumsi Pangan, 2018). The consumption of potatoes is rising, especially in the big cities where people prefer fast food to traditional rice. Therefore, the production of potatoes should be increased by increasing plant productivity. To increase plant productivity, the role of breeding programs is important, which highly depends on the availability of genetic variability.

The genetic variability of potato germplasm is an important aspect of success in the breeding program. Hybridization among parents with broad genetic variability may increase the genetic variability of the desired characteristics. The plant's

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Article History
Received: 20 Nov 2019
Accepted: 15 Oct 2021

characteristic variability that will be derived is the main requirement in breeding. The commercial potato varieties do not yet have many variations, due to the vegetative propagation of plants. Therefore, the induction of variability becomes one of the potato plant improvement programs (Mondal et al., 2007). Observation of qualitative and quantitative characterizations determines the next step in the breeding program.

The plant improvement program begins from observing qualitative and quantitative characteristics to determine the next step in the breeding program. The quantitative characteristics that play an important role include tuber yield and primary yield components (number of tubers per plant, tuber weight per plant, and tuber size). Tuber yield is an important characteristic as it measures the economic productivity of potatoes. Estimates of heritability and genetic advance among important characteristics could provide a basis information for efficient potato breeding programs and information on the performance of parents in hybrids (Mondal et al., 2007).

The genetic variability of 31 potato genotypes grown in Bangladesh indicated that plant height, the number of leaflets/compound leaf, leaf area, leaf coverage/plant, and fresh weight/compound exhibited high genetic advance and heritability. Therefore, these characteristics might be advocated to improve the yield by effective selection. Breeding is conditioned by the interrelationship of genotypic and environmental variation in different characteristics. In that case, the variability is divided into its heritable and non-heritable components with the help of suitable genetic parameters. Genotypic coefficient of variation (GCV), heritability estimates, and genetic advance are the genetic parameters. It is also beneficial to make a comparison for few characteristics that desirable ones in different strains (Nasiruddin et al., 2017). A similar study was also conducted to estimate the genetic variability and advance between the genotypes. The considerable variations among the genotypes studied were indicated by all genotypes varied significantly (Rahman et al., 2016).

Based on the combined analysis of variance performed over 2013 to 2014, were related Broad-sense heritability values of some quantitative characteristics in a potato population comprising 21 genotypes grown at Bornova, Izmir, Turkey, show that plant height, the number of tubers, the weight of single tuber, yield, and starch content had a moderate to high-level heritability values (Ozturk and Yildirim, 2014). So that the genotypic characteristic can be used as a guide in potato selection.

Highly heritability and correlation of potato genotypes were shown in fresh shoot weight, fresh root weight, root length, root diameter, number of root-knot, number of tubers, and tubers weight. All variables showed significant correlation so that it could be potentially used for characteristic selection, especially resistance varieties for nematode (Lubis et al., 2018). Such parameters with high heritability assessment can be used as selection criteria for plant breeding programs.

The information of gene action, genetic variability, and heritability is a useful tool for the selection in the crop improvement program and for designing efficient selection strategies in plant breeding. Many characteristics of potatoes are inherited in a quantitative manner. Selection is selecting the best individual plants based on the desired characteristics (Phillips and Wolfe, 2005). Selection will be effective if the right characteristic is used. The selection of the desired characteristic is based on its genetic values, such as heritability or correlation coefficient value (Nasution, 2010). Selection can be performed using one or several characteristics (Babu, 2012; Rachman, 2010).

This study aimed to determine agronomic characteristics that can be used as selection criteria in potato populations by estimating heritability, genetic variability, genotypic correlation, and selection of lines.

MATERIALS AND METHODS

The experiment was conducted at the Greenhouse, Sumber Brantas Village, Batu City, East Java. The treatment consisted of 30 lines of potatoes resulting from the crossing of LJPRSD1 x var AP-4 var [Lejifer Solanum Denisum x Ariza] x AP-4.]. The experiment was laid out in complete randomized design (RCD) with three replications. The research was started by sown the seeds in a nursery tub placed in the greenhouse using planting media of soil and cocopeat (1:1 v/v). Then, 30 lines/genotypes of potato seeds were planted in the polybag (24 seeds each line and one seed per polybag per hole), and the spacing used was 40 x 40 cm. The agronomic characteristics observed were plant height (cm), stem diameter (cm), number of leaves, the diameter of tuber (cm), number of tubers, length of tuber (cm), weight per tuber (g), levels of starch (%), and glucose (%).

The expectation of the square of each parameter, genotypic coefficient of variation (GCV), and phenotypic coefficient of variation (PCV) was calculated based on the formula by Singh & Chaudhary (1979). Genotypic variations were tested by analysis of variance at a 5% significance level based on Akmal et al., (2014).

The data obtained were analyzed of variance (Steel et al., 1997). The genotypic and phenotypic correlations were calculated by Kwon and Torrie (1964) technique. Estimation analysis of the value of genetic parameters used is as follow:

a). The estimation of broad sense heritability is based on the ratio of total genetic variance to total phenotypic variance (Zen, 2012). The following equation assumes the value of broad sense heritability.

$$h^2_{bs} = \frac{\delta^2_G}{\delta^2_P} \qquad (1)$$

According to Stansfild (1991) and Khan et al., (2007), the values of heritability are divided into three categories: high ($h^2 > 0.5$), moderate ($0.2 < h^2 \leq 0.5$), and low ($h^2 \leq 0.2$).

b). Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were calculated based on Singh & Chaudhary (1979) equation.

$$KK_G = \frac{\sqrt{\sigma^2_g}}{X} \times 100\% \qquad (2)$$

$$KK_P = \frac{\sqrt{\sigma^2_p}}{X} \times 100\% \qquad (3)$$

KK_G = Genotypic coefficient of variation
KK_p = Phenotypic coefficient of variation
σ^2_g = Genotypic variance
σ^2_p = Phenotypic variance
X = Rate

According to the following equation, the genotypic variance was determined based on genotypic variance and standard deviation of genotypic variance.

$$\sigma^2_G = \sqrt{\frac{2}{r^2}\left[\frac{KT_G{}^2}{db_G+2} + \frac{KT_E{}^2}{db_E+2}\right]} \qquad (4)$$

σ^2_g = Genotypic variance
KTG = Mean square of error
KTE = Mean square of environment
r = number of replications
dbG = degrees of freedom for error
dbE = degrees of freedom for environment

If $\sigma_G^2 > 2\sigma_G^2$: Broad genotypic variance, whereas $\sigma_G^2 < 2\sigma_G^2$: narrow genotypic variance (Pinaria et al., 1995).

c) Genotypic correlation coefficient was determined based on Singh and Chaudhary (1979) equation, then tested using Z test at the level of 5%. Correlation analysis is used to predict the closeness between agronomic characters, using the following equation.

$$\hat{r}_{xy} = \frac{Cov_{xy}}{\sqrt{\delta_x^2 \delta_y^2}} \qquad (5)$$

$\hat{r}_{xy}$ = correlation between x and y characteristics

Cov_{xy} = variability between x and y characteristics

σ^2_x = population variance for x characteristics

σ^2_y = population variance for y characteristics

d) To find out the direct and indirect effects of each characteristic on the yield, path analysis was used, as proposed by Singh and Chaudhary (1979) as follow:

$$R_{xy} = R_{xx} \times P_{xy} \longrightarrow P_{xy} = R_{xy} \times R\text{-}1_{xx}, \qquad (6)$$

R_{xy} = dependent and independent characteristic correlation values

$R\text{-}1_{xx}$ = matrix inverse between dependent characteristics

P_{xy} = cross correlation coefficient (direct effect)

RESULTS AND DISCUSSION

Determination of Genetic Variations

The standard deviation value of the agronomic characteristics of 30 lines of potato resulting from crossing is high, and the population range values are broad (Table 1). The analysis of variance showed that the genotypes of the lines resulting from crossing have a very significant difference in the plant height, stem diameter, number of leaves, the diameter of tuber, number of tubers, length of tubers, weight per tuber, starch content, and glucose (P-value <,0001). The significant values of the variable analysis indicate the variation between the lines for all characteristics tested so that selection can be made. According to Hartati et al., (2002) and Herawati et al., (2009), populations that can be selected are those that have high variability. Analysis of variance showed significant variation between the lines for all characteristics tested. Therefore, selection can be made.

Standard deviation and population range values are used to see the spread of values on agronomic characteristics. A high standard deviation and broad range values indicate that a character has diffuse data so that it has high variability (Singh and Chaudhary, 1979). Variability found in agronomic characteristics can also be predicted through the coefficient of variation and analysis of variance (Akhmadi et al., 2017).

The coefficient of variation for each agronomic characteristic is below 30 %. The coefficient of variation shows the heterogeneity of plants in the population (Zen, 2012). According to Bowman (2001), the lower the coefficient of variation found in the data, the higher the degree of accuracy. This shows the conclusions generated in this study have high validity.

Estimation of genetic parameters in the selection process is very important because the implementation of visual selection by selecting a good phenotype does not produce satisfactory results without being guided by the values of estimating genetic parameters carried out in the selection process. Variability as a genetic parameter in the selection process is one of the first steps in assembling new varieties. Plants with narrow genetic variability are not good enough to be used as parents in developing varieties. In contrast, plants with

Table 1. Average and population range values of agronomic characteristics of 30 potato lines resulted from crossing

Characteristics	Mean Square	Average ± SD	Population Range
Plant height (cm)	548.23**	37.97 ± 13.62	24.35 – 61.60
Stem diameter (cm)	0.48**	0.92 ± 0.24	0.68 – 1.16
Number of leaves	1474.07**	76.40 ± 33.13	43.27 – 109.53
Diameter of tuber (cm)	0.48**	2.56 ± 0.40	2.16 – 2.96
Number of tubers	47.33**	11.24 ± 4.06	7.18 – 15.3
Length of tubers (cm)	4.20**	6.44 ± 1.35	5.09 – 7.79
Weight per-tuber (g)	476.19**	29.40 ± 12.61	16.79 – 42.01
Starch content (%)	1.49**	6.07 ± 1.35	4.72 – 7.42
Glucose (%)	7.47**	1.94 ± 0.65	1.29 – 2.56

Remarks: ** significant ($P < 0.0001$)

Table 2. Genotypic variance, phenotypic variance, broad sense heritability, and genotypic phenotypic coefficient of variation values on several agronomic characteristics of 30 potato lines resulted from crossing

Characteristics	δ^2g	δ^2p	Heritability		Genotypic coefficient of variation (GCV)%		Phenotypic coefficients of variation (PCV)%	
			Value	Category	Value	Category	Value	Category
Plant height	182.36	183.50	0.99	High	0.35	High	0.36	High
Stem diameter	0.12	0.24	0.49	Moderate	0.13	High	0.19	High
Number of leaves	485.17	503.74	0.96	High	0.33	High	0.34	High
Diameter of tuber	0.15	0.18	0.83	High	0.15	High	0.17	High
Number of tubers	14.83	17.67	0.84	High	0.33	High	0.36	High
Length of tubers	0.93	2.34	0.40	Moderate	0.14	High	0.23	High
Weight per-tuber	158.72	158.75	1.00	High	0.43	High	0.43	High
Starch content	0.49	0.50	1.00	High	0.37	High	0.38	High
Glucose	2.47	2.53	0.97	High	0.26	High	0.26	High

broad genetic variability are likely to be developed into new varieties as desired. High variability can also improve selection response because the selection response is directly proportional to genetic variability. However, it is challenging to learn a characteristic by looking at genetic variability only. Another genetic parameters needed to study the character of a plant is heritability. Heritability is a genetic parameter that is used to measure the ability of a genotype in a plant population to inherit its characteristic or an estimation that measures the extent to which the appearance of a genotype in a population is mainly caused by the role of genetics (Acquaah, 2007; Govindaraj et al., 2014). In general, high heritability and high genetic variability will have a high genotypic coefficient of variation (GCV).

Broad-sense Heritability and Genetic Coefficient of Variance

Heritability shows whether genetic factors or environmental factors influence phenotype. If the heritability is high, genetic factors have more role than environmental factors, whereas if the heritability is low. The estimated value of heritability indicates that genetic and environmental factors influence the phenotype.

In this study, the broad sense heritability values range in Table 2. A total of 7 characteristics have a high heritability value, including plant height, number of leaves, the diameter of tuber, number of tubers, weight per-tuber, starch content, and glucose. Meanwhile, two characteristics have moderate heritability, including stem diameter and length of tubers. Similar results were also obtained, as reported by Pangemanan et al., (2013); Ozturk and Yildirim (2014) in several potato genotypes.

Heritability is a variable that determines whether the differences in the appearance of a characteristic are caused by genetic or environmental factors (Acquaah, 2007). High heritability value indicates that a character has large genetic variability, thereby providing opportunities for genetic improvement in plant breeding programs (Acquaah, 2007; Govindaraj et al., 2014). Selection can be performed more effectively on a characteristic with a high estimated heritability value. Agronomic genetic variability of 30 potato lines resulting from crossing is shown by a variability of genotypes and coefficients of variation, indicating broad criteria. The value of heritability ranges from high to moderate, as shown in Table 2.

Characteristics with high heritability values indicate that genotypes play a bigger role than environments' variability (Acquaah, 2007; Pratap et. al., 2012). If genotypes play a bigger role, the selection activities on a characteristic will provide meaningful genetic progress. The heritability value for the selected character determines the effectiveness characteristics (Pratap et. al., 2012). The influence of additive genes causes selection activities to be more effective (Sathya and Jebaraj, 2013). Jambormias et al., (2004) state that a high heritability value of a characteristic indicates that the phenotypic variability in that generation is caused by genetic variability. Good characteristics to be used as selection criteria are those who have high heritability values (Begum et al., 2013). According to Fehr (1987), selection on the characteristics with high estimated values of heritability can be performed on the early generation, while selection on the characteristics with low heritability is carried out in the late generation. According to Basavaraja et al., (2013), the knowledge of heritability determines the genetic advance under selection. Heritability and genetic advance are two selection parameters assessed during this study.

Genetic variability is expressed by the genotypic variance value and genotypic coefficients of variation. If the genetic coefficient of variation is higher than the genotypic deviation standard, the genetic variability is classified broad. Meanwhile, if the genetic coefficient of variation is equal to or smaller than the genotypic deviation standard, the genetic variability is classified narrow. Heritability in the broadest sense involves total genetic diversity (both addictive and dominant), and if it involves only the genetic variety of addictive, it is narrowly categorized.

These results indicate that the environment has little influence on the expression of a character because morpho-agronomic characteristics are generally influenced by additive genes (Kahrizi et al., 2010). Broad genetic variability in these characteristics indicates that these characteristics can be improved because they are more flexible to be selected (Yunianti, 2010). The genetic and phenotypic variance values are used to estimate the value of broad-sense heritability. According to Hallauer and Miranda (1981), the effectiveness of selection is highly dependent on the estimated value of heritability and the presence of genetic diversity of the selected material. The high estimated values of heritability and genotypic coefficient of variation of the observed characteristics are possible for effective selection (Haq et al., 2008). In addition, quantitative characteristic selection can be carried out based on the values of the genetic parameters without neglecting the middle value of the population concerned.

Coefficients of Correlation Between Agronomic Characteristics of Potato

Estimation of correlation analysis aims to study the relationships between characteristics and select the main characteristics that have always been the goals of improvement in each plant breeding pro-

Table 3. Correlation between several agronomic characteristics of 30 potato lines resulted from crossing

Characteristics	Plant height (cm)	Stem diameter (cm)	Number of leaves	Diameter of tuber (cm)	Number of tubers	Length of tuber (cm)	Weight / tuber (g)	Starch content (%)
Stem diameter (cm)	0.788**							
Number of leaves	0.786**	0.750**						
Diameter of tuber (cm)	0.571**	0.589*	0.359*					
Number of tubers	0.407*	0.382*	0.501**	0.359^{ns}				
Length of tubers (cm)	0.383^{ns}	0.230^{ns}	0.314*	0.501*	0.337*			
Weight /tuber (g)	-0.117**	-0.126**	-0.316*	0.314**	-0.221^{ns}	-0.238*		
Starch content (%)	0.531^{ns}	0.393^{ns}	0.458*	-0.316^{ns}	0.399^{ns}	0.396^{ns}	-0.086^{ns}	
Glucose (%)	0.605**	0.508**	0.465*	0.458*	0.032*	0.305*	-0.177^{ns}	0.386*

Remarks: ns: Not significant, *: Significant at alpha level of 5%, **: Significant at alpha level of 1%

Table 4. Direct and indirect effects of agronomic characteristics on the weight per tuber

Variables	Estimation of Direct	Estimation of Indirect								Total
		Plant height (cm)	Stem diameter (cm)	Number of leaves	Diameter of tuber (cm)	Number of tubers	Length of tubers (cm)	Starch content (%)	Glucose (%)	
Stem diameter (cm)	0.621	-	-0,100	-0.102	0.375	-0.281	0.025	0.143	-0.078	0.605
Number of leaves	-0.127	0.488	-	-0.105	0.352	-0.169	0.027	0.106	-0.065	0.508
Diameter of tuber (cm)	-0.178	0.355	-0.075	-	0.462	-0.230	0.068	0.124	-0.060	0.465
Number of tubers	0.921	0.253	-0.048	-0.089	-	-0.367	-0.067	-0.085	-0.059	0.458
Length of tubers (cm)	-0.733	0.238	-0.029	-0.056	0.462	-	0.047	0.108	-0.004	0.032
Weight /tuber (g)	-0.214	-0.073	0.016	0.056	0.289	0.162	-	0.107	-0.039	0.305
Starch content (%)	0.270	0.330	-0.050	-0.082	-0.291	-0.293	-0.085	-	0.023	-0.177
Glucose (%)	-0.128	0.376	-0.064	-0.083	0.422	-0.023	-0.065	-0.048	-	0.386

gram. Estimation of correlation analysis between the characteristics tested is shown in Table 3.

The results showed that almost all the characteristics studied were found to have positive and significant correlations. This indicates that a selection of one character will affect the other characteristics. In addition, positive and negative correlations indicate that changes in a characteristic will be followed by the changes in other characteristics regularly in the same and opposite direction, respectively. Characteristics that have a positive and significant correlation coefficient can be used as selection criteria because an increase in a characteristic will increase the other characteristics.

Characteristics that have a negative coefficient of correlation show the opposite response so that they are not used as selection criteria. Characteristics that have a positive correlation coefficient can be used as selection criteria by selecting individuals who have the highest characteristics values (Boer, 2011). According to Wirnas et al., (2006), characteristics negatively correlated with yield are not recommended as selection criteria. Selection will be more effective if it is also carried out indirectly through positively correlated characteristics with yield.

Estimation of Direct, Indirect and Total Effect of Agronomic Characteristics on the Weight per-Tuber

The direct and indirect effects of different characteristics were determined using path coefficient analysis in the correlation against yield, to get the interrelationships between different characteristics (Singh et al., 2004). Yield is a very complex character influenced by various characteristics so that selection based on the yield directly may not be very efficient (Mahajan et al., 2011). Therefore, knowledge of the relationship between yield and characteristics contributes is beneficial in evaluating and developing high-yield potatoes.

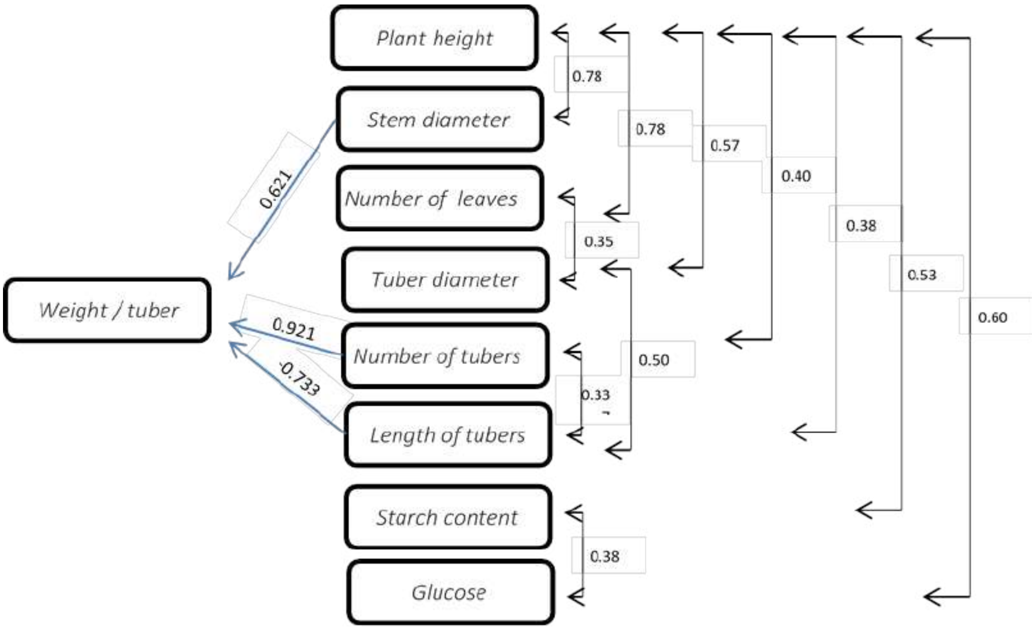

Figure 1. Path Analysis of Agronomic Characteristics on the Weight per-Tuber

The estimates of the direct, indirect, and total effects of yield components on the weight per tuber are presented in Table 4. A path diagram showing the relationships between yield and its components is presented in Figure1. Table 4 showed that tubers have the largest direct effect on weight/tuber, followed by the stem diameter. A direct effect of the number of tubers on the weight per tuber also involves the indirect effect of several variables. Stem diameter has a positive and significant correlation with the number of leaves. The number of leaves is positively correlated with the number of tubers. Thus, the number of tubers affects the weight per tuber. This result is due to the relationship between source and sink. The leaf as a source organ is positively correlated with the number of tuber and weight per tuber as sink organs.

In addition to genetic characteristics, a phenotype also plays a role due to environmental conditions. According to Su-May et al., (2015), at the germination or seedling development stage, to support initial growth of seedlings, minerals produced from the hydrolysis of stored nutrients in the endosperm (source) are transported to the embryo (sink). The result of photosynthesis (Sucrose) in mature leaves (source) is translocated through the phloem, to developing leaves (sink), at the vegetative stage. Sucrose is produced by photosynthesis and is translocated to developing tuber (sink), during the tuber-filling stage. Various nutrients, particularly N, and minerals in leaves (source) are also remobilized to developing tuber. The characteristics that can be used to determine the selection criteria have several considerations. These are genetically correlated strongly with the target characteristic, have a high heritability value, and be easily visually observed (Roy, 2000).

Selection of Potato Lines

The selection of the lines tested was based on heritability values, genetic coefficients of variation, genetic correlation coefficients, and the value of direct and indirect effects of agronomic characteristics on the yield. Selection of potato lines can be carried out using plant height, stem diameter, number of leaves, the diameter of tuber, number

Table 5. Selection of potato lines

Lines	Plant height [cm] 24.35-61-60	Diameter of tuber [cm] 2.16-2.96	Number of Tuber 7.18-15.3
UPRSD1-AP4-1	43.493	2.504	18.371
UPRSD1-AP4-2	60.770	2.515	12.068
UPRSD1-AP4-3	31.163	2.267	11.698
UPRSD1-AP4-4	49.378	2.532	9.558
UPRSD1-AP4-5	47.905	2.895	5.924
UPRSD1-AP4-6	47.279	2.729	11.150
UPRSD1-AP4-7	59.643	3.170	11.068
UPRSD1-AP4-8	48.274	2.592	13.180
UPRSD1-AP4-9	49.496	2.732	13.031
UPRSD1-AP4-10	31.823	2.197	10.101
UPRSD1-AP4-11	58.748	3.038	17.104
UPRSD1-AP4-12	41.759	2.259	17.816
UPRSD1-AP4-14	37.762	2.640	12.669
UPRSD1-AP4-15	56.518	2.921	11.623
UPRSD1-AP4-16	26.585	3.105	7.882
UPRSD1-AP4-17	34.522	2.371	9.809
UPRSD1-AP4-18	45.685	2.768	15.409
UPRSD1-AP4-19	19.651	1.896	5.077
UPRSD1-AP4-20	38.441	3.150	14.928
UPRSD1-AP4-21	35.102	1.771	14.068
UPRSD1-AP4-22	16.470	2.564	4.191
UPRSD1-AP4-23	9.064	1.710	14.327
UPRSD1-AP4-24	24.318	2.457	5.077
UPRSD1-AP4-25	39.695	2.117	12.993
UPRSD1-AP4-26	27.496	2.186	12.327
UPRSD1-AP4-27	26.363	2.514	9.990
UPRSD1-AP4-28	33.386	3.176	7.549
UPRSD1-AP4-29	46.519	2.530	11.409
UPRSD1-AP4-30	16.064	2.153	7.077
UPRSD1-AP4-36	38.587	2.629	19.327

of tubers, weight per tuber, starch content, and glucose. The selection of the lines tested was carried out by the criteria of plant height (24.35 - 61.60 cm), the diameter of tuber (2.16 - 2.96 cm), and the number of tubers (7.18 - 15.3). There were 15 selected lines that met the criteria (Table 5).

Selection is selecting the best individual plants based on the desired characteristic (Phillips and Wolfe, 2005). Selection will be effective if the right selection criteria is used. The selection of selection criteria is based on the characteristic's genetic values, such as heritability or coefficient of correlation values (Nasution, 2010). Selection can be done using one or several characteristics (Babu, 2012; Rachman, 2010). Based on research and analysis that has been done, it can be concluded that plant height, the diameter of tuber, and the number of tubers can be used as selection criteria.

CONCLUSION

1. The high heritability of 30 potatoes lines was found in the characteristics of plant height, number of leaves, the diameter of tuber, number of tubers, weight per tuber, starch content, and glucose.
2. The genetic variability of the 30 potatoes lines on the characteristic of plant height, number of leaves, number of tubers, starch content, glucose, and the weight per tuber is slightly low, while on the other characteristics is low. The lines produced are pure strains so that the individuals in the same line have almost uniform phenotypes.
3. The characteristics of plant height, stem diameter, number of leaves, the diameter of tuber, number of tubers, and glucose correlate with weight per tuber.
4. The agronomic characteristics in this study that can be used as selection criteria are plant height, the diameter of tuber, and the number of tubers.

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Weeding Frequencies Improve Soil Available Nitrogen in Organic Paddy Field

DOI 10.18196/pt.v10i1.12707

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ABSTRACT

Appropriate weeds control is needed against weeds constraints in field, especially the organic field. With the appropriate management, weeding would benefit the organic field not only in reducing weeds but also in increasing nitrogen (N) availability in organic rice fields. This research aims to observe soil available N changes affected by weeding frequencies in organic paddy fields. Treatments applied were five weeding frequencies (WF) such as 0 WF, 2 WF, 4 WF, 6 WF, and 8 WF, to study the effect of various weeding frequencies on soil total N and available N (NH_4^+ and NO_3^-) in the organic rice field. The soil in the conventional field was analyzed as a comparison to organic field soil. The results showed that soil C and N contents are similar in all treatments. Meanwhile, 6 WF performed the highest soil NH_4^+ among organic plots (10.36 mg N kg−1) and 8 WF enhanced soil NO3− to the highest average among all plots (10.12 mg N kg−1). The treatment of 6 WF and 8 WF also maintain the increase of soil NH_4^+ to 51 days after transplanting (DAT), meanwhile 0 WF, 2 WF, and 4 WF decreased after 40 DAT. Water samples from fields inlet-outlet and river showed that NH_4^+ content found in water sample was higher than NO3−. We concluded that the more frequencies of weeding applied to organic fields potentially preserved soil inorganic N longer, which is very important in supporting rice growth.

Keywords: Ammonium, Nitrate, Intensity of weeding, Organic weeds management, Rotary weeder

ABSTRAK

Pengendalian gulma yang tepat diperlukan untuk mengatasi kendala gulma di lahan, terutama di lahan organik. Dengan pengelolaan yang tepat, penyiangan akan bermanfaat bagi lahan organik tidak hanya dalam mengurangi gulma tetapi juga dalam meningkatkan ketersediaan nitrogen (N) di lahan sawah organik. Penelitian ini bertujuan untuk mengamati perubahan N tersedia tanah yang dipengaruhi oleh frekuensi penyiangan di lahan sawah organik. Perlakuan yang diberikan adalah lima frekuensi penyiangan (WF) yaitu 0 WF, 2 WF, 4 WF, 6 WF, dan 8 WF, untuk mempelajari pengaruh berbagai frekuensi penyiangan terhadap N total tanah dan N tersedia (NH_4^+ dan NO_3^-) di tanah sawah organik. Tanah di lahan konvensional dianalisis sebagai pembanding dari tanah di lahan organik. Hasil penelitian menunjukkan bahwa kandungan C dan N tanah memiliki nilai serupa pada semua perlakuan. Sementara itu, 6 WF memiliki kandungan NH4+ tanah tertinggi di antara plot organik (10,36 mg N kg−1) dan 8 WF meningkatkan NO_3^- tanah dengan rerata tertinggi di antara semua plot (10,12 mg N kg−1). Perlakuan 6 WF dan 8 WF juga terbukti dapat mempertahankan peningkatan NH_4^+ tanah hingga 51 hari setelah tanam (HST), sedangkan pada 0 WF, 2 WF, dan 4 WF terjadi penurunan setelah 40 HST. Sampel air dari inlet-outlet sawah dan sungai menunjukkan bahwa kandungan NH_4^+ yang ditemukan dalam sampel air lebih tinggi dari NO_3^-. Kami menyimpulkan bahwa penambahan frekuensi penyiangan yang diberikan pada lahan organik berpotensi mengawetkan N tersedia tanah lebih lama, yang sangat penting dalam mendukung pertumbuhan padi.

Kata kunci: *Amonium, Nitrat, Intensitas penyiangan, Pengendalian gulma organik, alat pemotong gulma putar*

INTRODUCTION

Rice is a staple food for people in the world, especially in most parts of Asia (Muthayya et al., 2014; Phukan et al., 2021). The sustainability of rice production faces challenges from various factors, including biological factors and physical environmental factors. Biological factors include genetics and physiology of rice, weed, and soil fauna and microbial. While the physical environmental factors, which there are climatic and soil factors (Long and Yabe, 2011; Bhatia et al., 2016; Wu et al., 2018).

The presence of weeds in rice paddy fields involve serious problem and tremendously affect

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Article History
Received: 08 Sep 2021
Accepted: 07 Sep 2022

rice production in quality and yield (Bajwa et al., 2015; Peng et al., 2021). Rice qualities are affected by weeds, such as crop bending and leaf rolling (Peng et al., 2021). The injuries caused by weeds would potentially impact rice growth and yield. Weeds caused yield losses with a range that was influenced by factors such rice management and ecosystem, rice cultivar, growth rate, and weeds itself (density and species) (Chauhan et al., 2014). The loss potential had been estimated at 35 to 47% in rice production (Johnson et al., 2004; Oerke and Dehne, 2004).

Herbicides were effective in removing weeds and increasing food production (Hikosaka et al., 2021). Herbicide development began in World War II, also known as the 'chemical era'. Herbicides are used to control weeds to date and are reported as the highest pesticide product, approximately 47.6% of global pesticide sales, followed by insecticides (29.4%), fungicides (17.5%), and others (5.5%)(Vats, 2015). Excessive use of herbicides causes a decrease in biodiversity , serious environmental and ecological issues on rice paddy fields, so that alternative methods have been considered to be applied (Li et al., 2019; Sardana et al., 2017). According to the terms of organic agriculture, non-chemical weeding was applied to control the weeds population (Bhatia et al., 2016). Suitable periods of weeding in the organic field decreased weeds and optimized crop yield (Latif et al., 2021; Phukan et al., 2021; Uno et al., 2021). Latif et al (2021) concluded that hoeing at 15 days after transplanting (DAT) followed by 30 DAT was the best treatment. Moreover, weeding in late periods was negatively affected growth and yield parameters.

Not only controlling weeds, but the organic farm also faces the hardship in supplying nutrients for the crops. The soil in organic rice fields cannot supply nutrients, especially N, as the conventional field. Weed exist in the fields, causing competition in nutrient uptake that will inhibit rice growth on reaching potential yield (Hazra et al., 2018; Martínez-Eixarch et al., 2017). While, deficiency of N has been a primary constraint in lowland rice productivity (Sahrawat, 2006). Nitrogen (N) has been known as an essential and labile nutrient in the paddy field. Paddy soils capability in supplying N has a high impact on rice yield (Dewi et al., 2018; Ishii et al., 2011; Nguyen et al., 2020).

Moreover, incorporating weeds contributed to scavenged soil nitrogen (Huang et al., 2018); suppressed weed growth, increased the amount of inorganic nitrogen (Ardiantika et al., 2018; Utami et al., 2020); mineralizable soil nitrogen (Tanaka et al., 2012; Toriyama et al., 2020); and soil available Phosphorus (Sakuraoka et al., 2018). It is indicated that weeding practices and weed returning to the soils will increase and provide available nitrogen for rice. Previous research has established that 21.2% of the total mineralizable soil N formed originally from weed, while 78.8% was from indigenous soil organic N after years (Toriyama et al., 2020). This proves that in organic rice, weeds must be managed to make a significant contribution to the availability of N.

In Japan, rice straw (RS) is commonly incorporated into the soil after harvest to maintain the fertility of paddy soil (Nguyen et al 2020). This method has been applied in this organic research field for 10 years. Other than that, weeds biomass also left decomposed naturally in the field. Related to farmer habits in controlling weeds using rotary weeder, we assumed that the addition of frequencies in weeding application would have roles in controlling weeds and supplying more soil N in the organic field, which would support optimizing rice growth. Research in weeds management is essential, especially in the organic field, to reach optimum yield. Moreover, the relation between weed pressure and soil fertility is important to be studied

(Bhatia et al., 2016; Jerkins and Ory, 2016). Our research aimed to find the most effective weeding frequencies in supplying soil N in the organic fields, especially soil inorganic N. To reach the purpose of this study, we applied different frequencies of weeding in the early stage of rice growth.

MATERIALS AND METHODS

Experimental field and management

This experiment was located at Yamagata University Farm, Tsuruoka, Yamagata prefecture, northeastern Japan (38°41'55 N 139°49'15 E) (Figure 1). The soil in Trsuruoka was classified as Inceptisols. Two fields were observed, organic and conventional rice fields; each field size was 30 x 100 m. One of the popular Japanese rice cultivar, cv. Sasanishiki was transplanted on May 25th, 2019, and harvested on September 23rd, 2019. The planting distance was 32 x 15 cm in the organic fields and 30 x 15 cm in the conventional fields. The irrigation system was technical irrigation, where the outlet was directed to the river between organic and conventional fields.

Fertilizer and herbicide were applied in the conventional field, while no fertilizer was applied in the organic field. In ten years, mechanical weeding with rotary weeder was applied to control the organic fields by disturbing inter-row weeds. Treatment in this study was weeding frequencies in the organic field. There were five weeding frequencies (WF) treatments, namely, 0 WF, 2 WF, 4 WF, 6 WF, dan 8 WF, with four replications for each treatment. All weeding frequencies were applied from 7 to 49 DAT (days after transplanting).

Soil sampling and analysis

The soil was sampled four times using a hand trowel from the surface layer (0–1 cm) and sublayer (1–10 cm) soil depth at 18, 29, 40, and 51 DAT. In addition, three other soil samples (at 60, 88 and 110 DAT) were taken when taking plant samples using a metal frame. The total soil samples were seven times during the growth of rice plants. The data surface layer and sublayer were calculated using the arithmetic mean of 0–10 cm depth. Concentration of NH_4^+ (ammonium) and NO_3^- (nitrate)

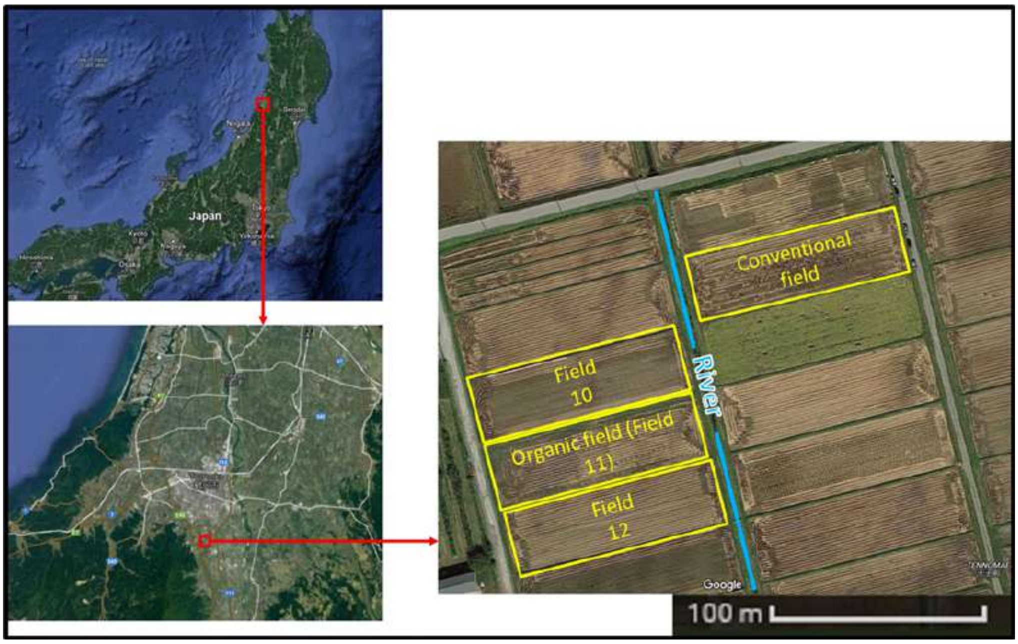

Figure 1. Research location in Yamagata University Farm, Takasaka, Tsuruoka, Japan (Source: https://www.google.com/maps)

Table 1. Effect of weeding frequencies on soil organic carbon (SOC), total nitrogen (TN) at 110 DAT (days after transplanting).

Treatments	SOC (g C kg–1) ± SD	TN (g N kg–1) ± SD
0 WF	19.45 ± 3.49 a	1.73 ± 0.29 b
2 WF	18.95 ± 1.18 a	1.67 ± 0.17 b
4 WF	19.47 ± 1.29 a	1.76 ± 0.18 b
6 WF	19.91 ± 3.88 a	1.83 ± 0.34 b
8 WF	20.85 ± 1.31 a	1.87 ± 0.11 b
Conventional	21.94 ± 1.88 a	1.87 ± 0.15 b

Remarks: 0 WF, 2 WF, 4 WF, 6 WF, and 8 WF were 0, 2, 4, 6, and 8 times mechanical weeding until 49 DAT. Values followed by the same letter in the same column are not significantly different according to Tukey's HSD ($p < 0.05$) test.

were extracted by 5 g of fresh soil using 30 ml of 10% KCl. Then, analysed by the nitroprusside and hydrazine reduction methods, respectively. Hitachi U–2900 Spectrophotometer (Hitachi High-Tech Science Corporation, Tokyo, Japan) was used for NH_4^+ and NO_3^- reading of absorbance at 655 nm and 540 nm, respectively. Soil organic carbon and total nitrogen were measured by dry combustion method using Sumigraph NC 220F Analyzer (Sumika Chemical Analysis Service, Ltd., Osaka, Japan).

Water sampling and analysis

Water samples were collected at 18, 29, 40, and 51 DAT. The location for water sampling was located in the river and each field water inlet and outlet. All samples were placed in plastic bottles then filtered using filter paper (Advantec 6, Toyo Roshi Kaisha, Ltd., Japan). Inorganic nitrogen (NH_4^+ and NO_3^-) was determined by the same method as soil analysis.

Statistical analysis

One-way analysis of variance (ANOVA) was applied to compare the difference in all parameters, and means between treatments were compared by Tukey's HSD (honestly significant difference) at $p < 0.05$. All statistical analyses were conducted in SPSS 22.0 for Windows (IBM Corp., Armonk, NY, USA).

RESULTS AND DISCUSSION

Soil carbon and nitrogen

Weeding frequencies was not influenced soil organic carbon (SOC) and total nitrogen (TN) concentration significantly (Table 1). SOC and TN in organic plot were not significantly different compared to conventional. These results indicated that weeding could not significantly influence SOC and TN in one season. Among weeding frequencies, 8 WF had the closest soil C and N concentration to the conventional plot reaching the highest soil C and N. Moreover, 8 WF also had the same concentration of soil N with the conventional plot.

Soil NH_4^+ in 4 WF, 6 WF, and 8 WF was increased at 29 to 40 DAT (Figure 2a). The highest soil NH_4^+ was in 6 WF (25.27 mg N kg^{-1}) and 8 WF (24.27 mg N kg^{-1}) in 51 DAT that differently significant with other treatments ($P < 0.05$). Moreover, 6 WF and 8 WF NH_4^+ were continued to increase and reached the peak at 51 DAT and then decreased. After that, soil NH_4^+ was relatively constant from 60 DAT to 110 DAT in all weeding frequencies. Meanwhile conventional field reached soil NH_4^+ peak in 29 DAT and then constantly decreased (Figure 3).

There was an increment on soil NO_3^- up to 40 DAT in all treatments (Figure 2A). Similar to soil NH_4^+, 0WF performed lowest in soil NO_3^- at all sampling periods that was counted in average by 7.82 mg N kg^{-1}. Whereas 8WF soil reached the

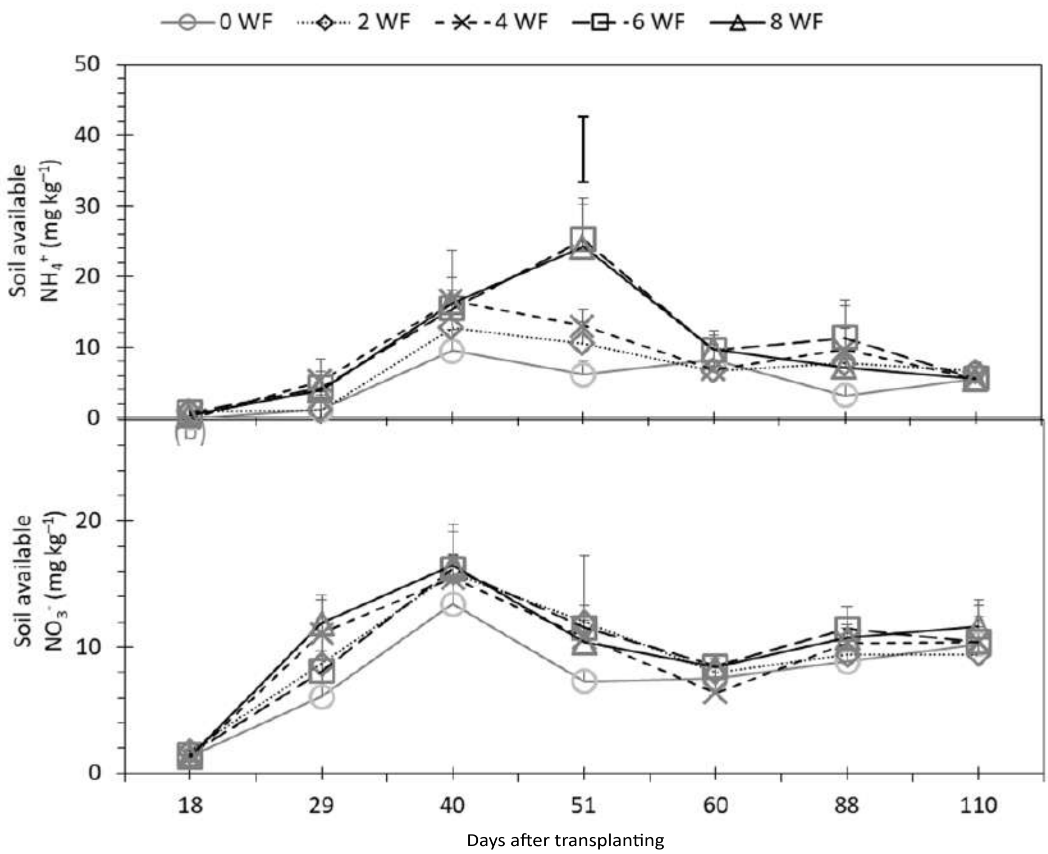

Figure 2. Effects of weeding frequencies on (a) NH4+ concentration in organic field, (b) NO3– concentration in organic field at 18, 29, 40, 51, 60, 88, and 110 DAT (days after transplanting). Bars in each value indicate standard deviation (n=4). Thick bar over standard deviation bar showed statistically different at $p < 0.05$ based on Tukey's HSD test. 0 WF, 2 WF, 4 WF, 6 WF, and 8 WF were 0, 2, 4, 6, and 8 mechanical weeding frequencies until 49 DAT.

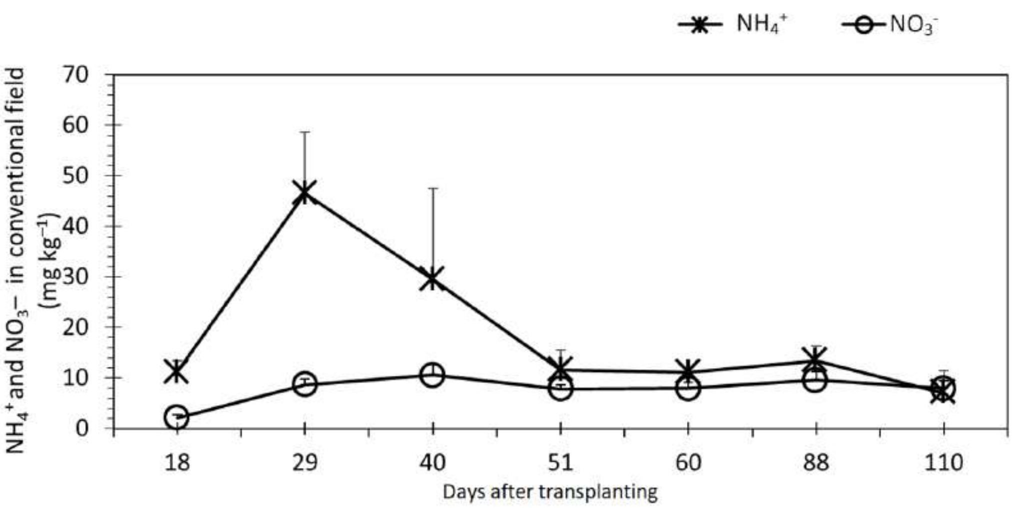

Figure 3. Soil NH4+ and NO3– in conventional field at 18, 29, 40, 51, 60, 88, and 110 DAT (days after transplanting). Bars in each value indicate standard deviation (n=4).

highest nitrate in the average of 10.12 mg N kg^{-1}. The soil in the conventional fields reached the peak of NH_4^+ (38.62 mg N kg^{-1}) at 29 DAT sampling periods (Figure 3). Then gradually decreased until 110 DAT, but still occupied as the highest in 110 DAT, 6.80 mg N kg^{-1}. Meanwhile, soil NO_3^- in conventional was lower than organic plot, and the amount was 7.81 mg N kg^{-1} on average. The changes of conventional soil NO_3^- were increased until 40 DAT and tended to have stable amounts until 110 DAT.

Weeding frequencies did not differ significantly in SOC or TN ($P > 0.05$). Yet, there was a slight increase in both parameters with the highest SOC and TN in conventional (21.94 g C kg^{-1} and 1.87 g N kg^{-1}) and 8WF (20.85 g C kg^{-1} and 1.87 g N kg^{-1}) (Table 1). These findings contrast with de Rouw and Rajot (2004) mentioned that organic matter increment in wheat fields without weed control caused by weed biomass was grown optimum and supplied more carbon than field applied weeds removal. The difference may be caused by different field management, which there was manure spreading that supported weed's growth (de Rouw and Rajot, 2004).

The amount of NH_4^+ was found higher than NO_3^- due to a flooded irrigating system that supported soil with NH_4^+through ammonification (Hantush et al., 2013; Liu et al., 2008; Utami et al., 2020; Zhang and Scherer, 2000). Ishii et al. (2011) mentioned that nitrification and denitrification occurs in different places. Nitrification ($NH_4^+ \rightarrow NO_2^- \rightarrow NO_3^-$) was in the thin oxidized soil surface layer, whereas denitrification ($NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$) occurs within a reduced soil layer below the oxidized layer. Mostly, nitrate is drained in the reduced soil below the thin oxidized layer at the surface, this mechanism is related to high denitrification activity (Nojiri et al., 2020).

Conventional fields showed the highest NH4+ since the early rice growth stage due to nitrogen fertilizer application (Figure 3). Whereas soil NH4+ in the organic field, much less found in this field only rely on decomposed weed biomass residue and rice straw from previous growing seasons. This condition occurred due to N supply rate from fertilizer being faster than weeds and rice biomass decomposition.

Soil inorganic N in early periods showed in low amount. Then, ammonium and nitrate were slowly increased in the organic field due to the activity of weeding applied where soil NH_4^+ 6 WF and 8 WF was highest, compared to other treatments. Besides, ammonium and nitrate were slowly increased in the organic field due to the decomposition of organic matter or mineralization (Ishii et al., 2011). In this study, NH_4^+ and NO_3^- could be produced from the remaining rice straw and weeds decomposition. In line with Maimunah et al. (2021), adding more weeds (in weeding practical) increased the N concentration of both rice and weeds. Then, the returns of plants biomass could support a high amount of NH_4^+ in the organic fields.

This study found in the organic field that 6 WF was found to perform highest NH_4^+ (10.36 mg N kg−1 in average) and highest NO_3^- in 8 WF, 10.12 mg N kg^{-1} in average. Soil NH_4^+ was more affected in a short time after weeding practice was applied (Figure 2). The incorporation of weeds increased mineralized nitrogen (Chen et al., 2014; Utami et al., 2020). Mechanical weeding used in this study supported higher mineralization. Weeding frequencies impacted higher inorganic N. Furthermore, NH_4^+ content in soil is very important and needed most in the rice tillering period, especially the first 20 DAT (Sasaki et al., 2002). Yet, the highest NH_4^+ in the organic field reached 6 WF and 8 WF at 51 DAT.

Inorganic nitrogen in water

This study observed whether management applied in the rice fields would affect inorganic N content in water. Similar to soil inorganic nitrogen, the value of the concentration of NH_4^+ in water tend to be higher than the concentration of NO_3^- in water (Figure 4 and Figure 5). This may be contributed by the mineralization of dissolved organic matter in water becoming NH_4^+ and the conversion of NO_3^- to NH_4^+. Continuously anaerobic conditions with abundant organic substrate and limited electron acceptor availability caused reduction of NO_3^--N to NH_4^+ more efficient than N_2 formation (Meng et al., 2014). Collected water from the inlet and outlet

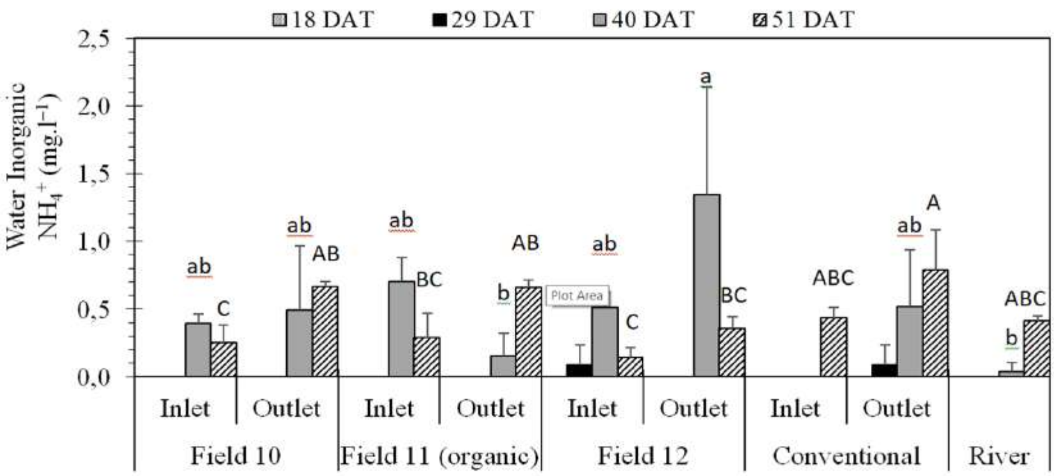

Figure 4. NH4+ concentration on water from inlet and outlet in east side of organic field (Field 10), organic field (Field 11), north side of organic field (Field 12), conventional, and river. Bars showed standard deviation (n=3). Letters above standard deviation bars showed significant difference at p < 0.05 based on Tukey's HSD test each DAT.

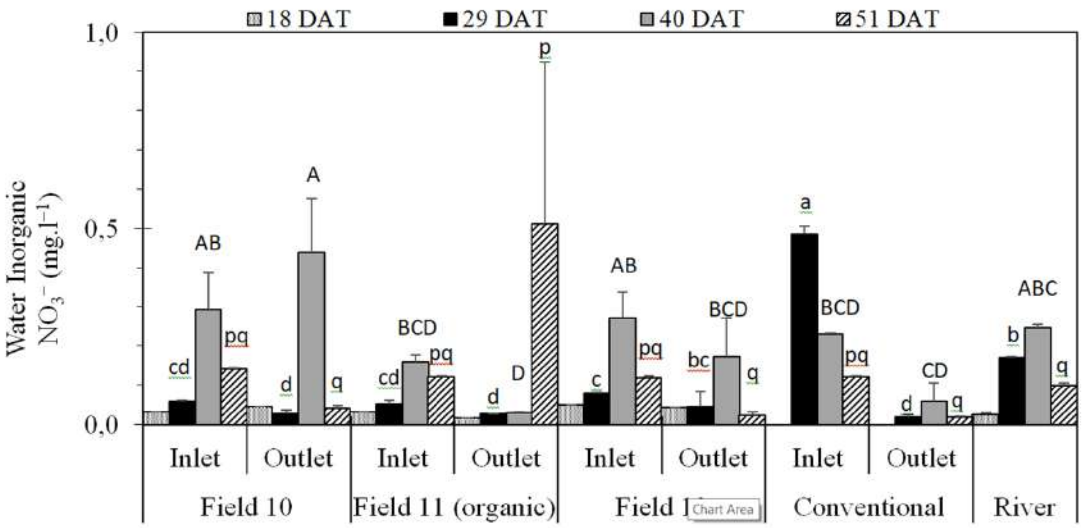

Figure 5. NO3- concentration on water from inlet and outlet in east side of organic field (Field 10), organic field (Field 11), north side of organic field (Field 12), conventional, and river. Bars showed standard deviation (n=3). Letters above standard deviation bars showed significant difference at p < 0.05 based on Tukey's HSD test each DAT.

of the fields observed whether NH_4^+ and NO_3^- in water has significantly contributed to rice growth. Compared to water collected from field 10 and field 12 located adjacent to the organic field, the concentrations of NH_4^+ in the inlet of the organic fields received more or less similar concentrations (Figure 2). The concentration of NO_3^- collected from inlet of field 10 and field 12 showed an approximately similar concentration with the organic field (Figure 4). The water inlet and the outlet were located in each field. Those facts implied that each field has received an approximately similar amount of NH_4^+ and NO_3^- from the same source and may also indicate no water seepage among field 10, organic field, and field 12. NH_4^+ and NO_3^- concentration in organic fields water were approximately the same as conventional fields located across the river.

The concentration of NH_4^+ in outlet water of all fields tended to be higher than their inlet water and increased until 51 DAT. River water sample also showed a similar trend, which reached its highest NH_4^+ concentration in 51 DAT (Figure 4). The concentration of NO_3^- in river water reached its peak in 110 DAT (0.37 mg N l^{-1}) (Figure 5). Concentration of NO_3^- in inlet water tended to be higher than outlet in all fields, except for organic field. Concentration of NO_3^- of the organic field showed higher in inlet water than outlet water, which was in a total of 0.699 and 0.468 mg N l^{-1}, respectively. Compared with the organic field, the conventional field indicated contrary, NO_3^- measured in the inlet was much higher than the outlet.

There was a change in the concentration of NH_4^+ and NO_3^- in inlet water and outlet water, indicating that NH_4^+ and NO_3^- dissolved in water was utilized by rice in organic and conventional fields. It seemed that the water can be a secondary source of NH_4^+ and NO_3^- for rice growth in organic and conventional fields. The concentration of NH_4^+ in inlet and outlet water of organic field at 18 and 29 DAT were below the detectable value. In contrast, the concentration of NO_3^- in inlet and outlet water of organic fields at 18 and 29 DAT was lower than the other rice growth stage (40 and 51 DAT). In 18 and 29 DAT, rice was under the tillering stage. Weeding practices at those stages were very important in the organic fields since they became the main nitrogen source. The concentration of NH_4^+ in inlet water of conventional field at 18 and 29 DAT was lower than outlet water, whereas the concentration of NH_4^+ in inlet water of conventional field at 18 and 29 DAT was higher than outlet water. This may be related to applying inorganic fertilizer as a nitrogen source in conventional fields.

Both concentrations of NH_4^+ and NO_3^- at 51 DAT were highest in the outlet of organic field, which was 0.66 and 0.51 mg l^{-1}, respectively. Possible cause for this condition was the last weeding applied (at 49 DAT) in the field was the practice of weeding removal using rotary hoe that would stir weeds and surface soil. This practice was believed to impact on soil nitrogen fractions and aeration produced, then the mobility of nitrogen increased (Sudhalakshmi et al., 2005). As rice growth above 51 DAT was the time of stem elongation to panicle initiation, the need for nitrogen was decreased. Whereas, during a maximum tillering period (40 DAT), inlet water of organic field performed the highest peak of NH_4^+ between plots inlets. Whereas, in the same period conventional outlet reached the highest peak (1.29 mg l^{-1}) among other plots.

Compared to the amount of soil available NH_4^+ and NO_3^- of organic field and conventional field (Figures 2 and 3), the concentration of NH_4^+ and NO_3^- in the inlet or outlet water at 18, 29, 40, and 51 DAT in the conventional and organic field was much lower, which may indicate that the contribution of NH_4^+ and NO_3^- from water source was relatively insignificant. The source of inorganic nitrogen for rice growth was ultimately from soil available NH_4^+ and NO_3^- due to weeding treatment. This finding indicated that weeding frequencies should become the component of good land management in organic agriculture.

CONCLUSION

Weeding frequencies influenced available soil N, then impacted water inorganic N significantly instead of SOC and TN. Mechanical weeding applied potentially supported higher mineralization so that more weeding frequencies affected to higher soil inorganic N. Water Inorganic N content showed that NH_4^+ value was higher than NO_3^-. Thus, weeding frequencies are suitable alternative methods to support organic field management. Furthermore, we recommend 6WF as the most effective weeding frequency to supply more soil available N in organic rice farming.

ACKNOWLEDGMENTS

Margi Asih Maimunah, as the first author, acknowledges the Japan Students Services Organization (JASSO) to support studies in the Faculty of Agriculture, Yamagata University, Japan, from September 2019 to August 2020. Special thanks to all members of Soil Science and Plant Nutrition Laboratory, Faculty of Agriculture, Yamagata University for their cooperation during research, and all authors that contributed to this paper writing.

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Epiphytic Weeds Control by Root Infusion Method in Oil Palm

DOI: 10.18196/pt.v10i1.10802

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ABSTRACT

Epiphytic weeds living on oil palm trunks will complicate harvesting activities. In addition, the presence of this weed can increase the risk of accidents being hit by fruit during harvesting. The objective of this research was to obtain herbicide and its efficient concentrations to control epiphytic weeds using root infusion method. The research was arranged in a single factor completely randomized design (CRD) with five treatments and five replications. Active ingredients of herbicide that used were methyl metsulfuron at a concentration of 20%, 30%, and 40%, glyphosate 30%, and triclopyr + diesel fuel at a ratio of 1:19. All treatments except triclopyr were diluted in 100 ml water for each epiphytic weed. Weed mortality rate (%) was observed every week for one month. The results showed that a solution of 30% methyl metsulfuron herbicide in 100 ml of water and 30% glyphosate in 100 ml of water was the most optimal treatment in controlling epiphytic weeds. Cutting the entire suction root of epiphytic weeds can increase the chance of weed mortality.

Keywords: Epiphytic weed, Herbicide, Oil palm, Root infusion

ABSTRAK

Gulma epifit yang hidup di batang kelapa sawit akan mempersulit kegiatan panen. Selain itu, keberadaan gulma ini dapat meningkatkan resiko kecelakaan kerja berupa tertimpanya pemanen oleh buah yang diturunkan. Penelitian ini bertujuan untuk menemukan bahan aktif herbisida dan konsentrasi yang tepat untuk mengendalikan gulma epifit dengan metode infus akar. Penelitian ini menggunakan Rancangan Acak Lengkap (RAL) faktor tunggal dengan lima perlakuan dan lima ulangan. Bahan aktif herbisida yang digunakan adalah larutan metil metsulfuron dengan konsentrasi 20%, 30%, 40%, glifosat 30%, dan triklopir + solar dengan perbandingan 1:19. Semua perlakuan kecuali triklopir dilarutkan dengan air 100 ml pada masing-masing gulma epifit. Tingkat kematian gulma (%) diamati setiap minggu selama satu bulan. Hasil penelitian menunjukkan bahwa larutan herbisida metil metsulfuron 30% dalam 100 ml air dan glifosat 30% dalam 100 ml air merupakan perlakuan yang paling optimal dalam mengendalikan gulma epifit. Pemotongan seluruh akar hisap gulma epifit dapat meningkatkan peluang kematian gulma dibandingkan dengan tanpa pemotongan akar yang lain.

Kata kunci: *Gulma epifit, Herbisida, Infus akar, Kelapa sawit.*

INTRODUCTION

Weeds are plants that can harm cultivated plants either directly or indirectly. The presence of weeds in oil palm plantations must be controlled so as not to interfere with operational activities and cause a decrease in production. Controlling weeds in the planting area, harvesting path, and yield shelters (TPH) is a routine maintenance program carried out with rotation and certain herbicides. Not only living in the soil, but weeds can also grow and attach to the stems of oil palm plants. Weeds growing on oil palm trunks are known as epiphytic weeds (Essandoh et al., 2011). These weeds live by depending on oil palm plants but do not absorb nutrients from their host plant (Compton & Musgrave, 1993). Epiphytic weeds absorb nutrients by competing for nutrients in the soil when fertilization is applied to oil palm plantations. Epiphytic weeds have better adaptability to water deficits (Adibah and Ainuddin, 2011). Thus, it enhances water competition with main crops. Epiphytic weeds can multiply rapidly through the ability to produce high seeds and allow them to spread to other areas (Bartoli et al., 1993).

Epiphytic weeds commonly found in oil palm plantations are ferns, banyan (*Ficus* sp), and woody weeds (Ginting et al., 2004). Banyan roots and

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Received: 08 Jan 2021
Accepted: 11 Dec 2022

woody weeds that live in epiphytes will wrap around the oil palm trunk until it enters the ground to find water and sources of nutrition. In large numbers and with large sizes, the presence of these weeds is able to break the stems of the plants on which they grow (Bayu et al., 2004). This weed can grow at the bottom, middle, and top of the oil palm trunk.

This can happen with the help of birds landing on the remaining pieces of the midrib attached to the oil palm trunk so that the seeds carried by the birds then germinate and grow. The growth of epiphytic weeds in the middle or top of the oil palm trunk is supported by the organic materials accumulated in the former pieces of oil palm fronds (Sofiyanti, 2013). The organic materials become the initial media for the growth of epiphytic weeds that develop through seeds. Weed transfer by birds (ornitochori) generally occurs in weeds that produce seeds (Mangoensoekarjo & Soejono, 2015). Several bird species reported to eat Ficus sp seeds are common myna (*Acridotheres tristis*), zebra doves (*Geopelia striata*), spotted doves (*Streptopelia chinensis*), and sparrows (*Passer domesticus*) (Starr et al., 2003). Several species of these bird species are reported to live and thrive in oil palm plantations (Kissinger et al., 2016; Ahmad et al., 2016; Seprido, 2020).

The presence of epiphytic weeds can disturb the harvest process, especially on tall trees. It causes difficulty for harvesters because the oil palm fruits are hindered by the shade of epiphytic weeds, thereby resulting in reduced production. In addition, the presence of these weeds can also increase the risk of work accidents for harvesters. Harvested fruit can swerve when it falls due to colliding with epiphytic weed stems and can hit workers. Incidents like this can be dangerous for oil palm harvest workers. This weed is commonly found in plantations located not far from the forest and will grow and develop on oil palm plants that are more than 15 years old (Kuvaini, 2011). Epiphytic weed control policies have been adopted by several oil palm plantations for years with the aim of simplifying the harvesting process (Ferwerda, 1977).

Epiphytic weed can be controlled manually and chemically. Control by cutting or pulling does not show good results. Manual control by pulling or slashing can be done when the epiphytic weeds are still small, growing at the base of the oil palm trunk. The big-size weeds will be more effectively controlled using chemical methods through the foliar spray and stem smear. However, it is relatively ineffective to control epiphytic weeds growing in the middle or top of the oil palm trunk because they are difficult to reach. Selective herbicides sprayed with a high-pressure spray machine provided effective chemical control (Bartoli et al., 1993). A root infusion is a feasible method expected to provide effective results of epiphytic weed control. The root infusion technique is carried out by dipping the roots of the target plant into a herbicide solution, which is then absorbed by the plant and poisons the target plant. Control by spraying techniques requires expensive costs through pumping machines that must be prepared. Therefore, this study was conducted to obtain active ingredients and effective and efficient concentration of herbicides for epiphytic weed control using root infusion control techniques.

MATERIALS AND METHOD

The research was conducted from May to August 2020 at the Pundu Nabatindo Estate (PNBE) Palm Oil Plantation, PT Bumitama Gunajaya Agro, Central Kalimantan. The research location is in a block with haplohumods soil type and 22-year-old oil palm plantations. The herbicide's active ingredients used were glyphosate, methyl metsulfuron, triclopyr, diesel fuel, and water as a solvent.

The research was arranged in a single factor completely randomized design (CRD) consisting of five treatments with five replications, resulting in a total of 25 experimental units. The treatments tested were 20% methyl metsulfuron (P1), 30% methyl metsulfuron (P2), 40% of methyl metsulfuron (P3), 30% glyphosate (P4), and triclopyr + diesel at a ratio of 1:19 with a total of 100 ml of solution (P5). All treatments except triclopyr were dissolved with 100 ml of water on each epiphytic weed.

The herbicide solution was mixed according to the treatment being tested and stirred until it was completely dissolved. The root infusion method was carried out by first finding the main roots or suction roots that spread into the soil. The main roots of the epiphytic weeds were put in a plastic bag containing the herbicide solution according to the treatments and tied tightly using a rubber rope to prevent water from entering the plastic bag, while other roots were cut. Visual observation of weed mortality was made once a week for one month.

Analysis of variance (ANOVA) was performed on the weed mortality rate (%), continued with the Honest Significant Difference (HSD) test at the 5% level. Data analysis was carried out with the help of Minitab 18 software and Microsoft Excel 2010.

RESULTS AND DISCUSSION

Weed Mortality Rate

The results of analysis of variance showed that root-infused herbicide solution significantly affected the mortality rate of epiphytic weeds 1-4 weeks after application (WAA) (Table 1). The treatments showing the most optimal results at 4 WAA were methyl metsulfuron at a concentration of 30% (P2) and glyphosate at a concentration of 30% (P4), producing epiphytic weed mortality rates of 88% and 89%, respectively. This result is in line with the research results of Simanjorang (2003) and Hengki et al. (2018), which showed that the active ingredients methyl metsulfuron and glyphosate could provide a high mortality rate of epiphytic weeds. Epiphytic weed leaves treated with 30% methyl metsulfuron (P2) and 30% glyphosate (P4) were almost completely dry, falling off at four WAA. Meanwhile, the treatment with the lowest mortality at four WAA (25%) was triclopyr + diesel at a ratio of 1:19 (P5) (Figure 1.).

Table 1. Symptoms of the epiphytic weed mortality at one to four weeks after application (WAA)

Treatments	Mortality symptoms (%) after application			
	1	2	3	4
20% Methyl metsulfuron (P1)	5 c	24 b	63 b	68 b
30% Methyl metsulfuron (P2)	16 b	28 ab	68 ab	88 a
40% Methyl metsulfuron (P3)	28 a	38 a	79 a	84 a
30% Glyphosate (P4)	9 bc	28 ab	69 ab	89 a
Triclopyr + Diesel (1:19) (P5)	5 c	20 b	30 c	45 c

Remarks: Means followed by the same letters are not significantly different according to the HSD test at 5%.

Table 2. Cost analysis of epiphytic weed control

Treatments	Cost of material per application ID(R)
20% Methyl metsulfuron (P1)	2,400
30% Methyl metsulfuron (P2)	3,600
40% Methyl metsulfuron (P3)	4,800
30% Glyphosate (P4)	660
Triclopyr + Diesel (1:19) (P5)	1,385

Early symptoms of weed mortality began to appear in one week after application in all treatments in the form of yellowing and leaf drop. Leaf drop can be seen easily on the soil surface (Figure 2).

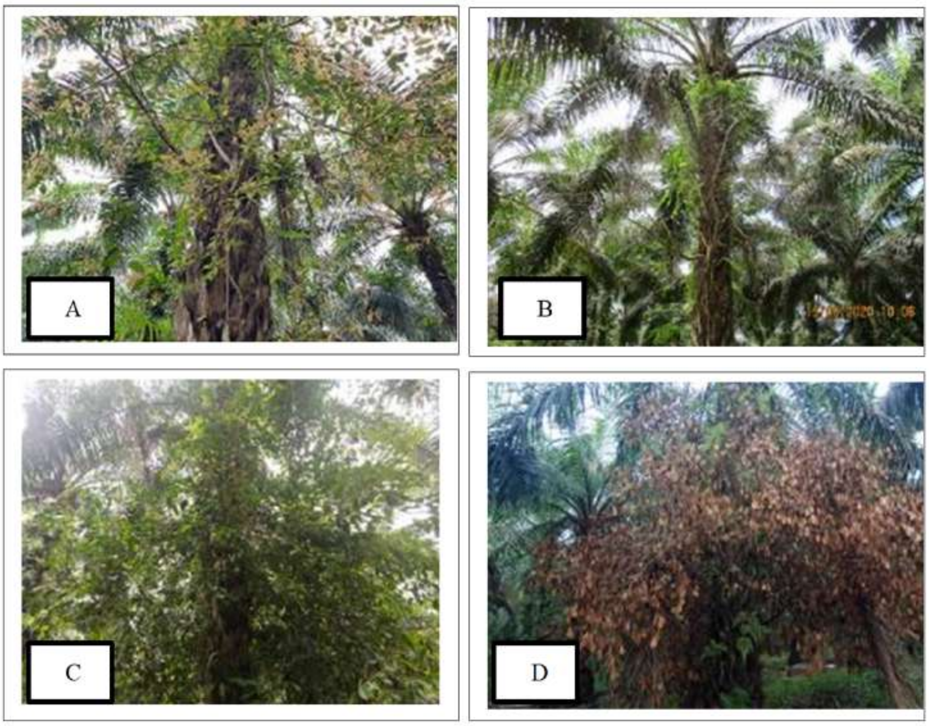

Figure 1. Epiphytic weed condition before (A) and after (B) the application of P2; before (C) and after (D) the application of P4 at four weeks after application

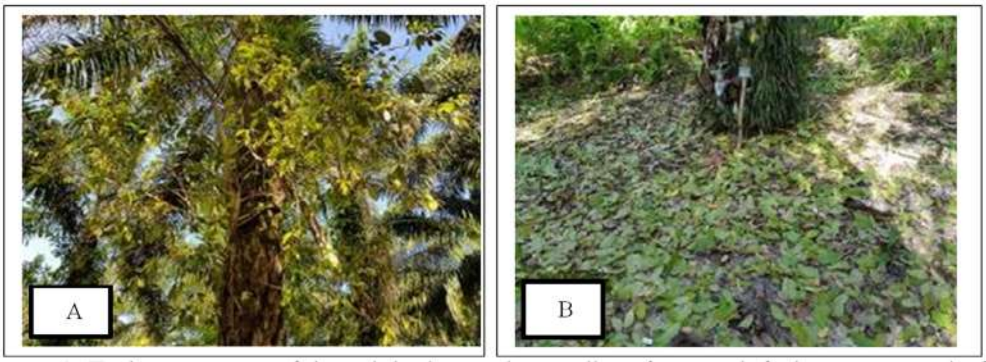

Figure 2. Early symptoms of the epiphytic weed mortality after root infusion treatment include leaf yellowing (A) and leaf drop (B)

Leaf symptoms in the form of chlorosis (yellowing) and necrosis (brown and dead) usually appear one to two weeks after herbicide application (Marble et al., 2016). Treatment of 30% methyl metsulfuron (P2) showed higher mortality symptoms and was significantly different compared to 20% methyl metsulfuron (P1), yet it was not significantly different from the treatment of 40% methyl metsulfuron (P3). Methyl metsulfuron is a systemic herbicide that inhibits the production of three amino acids needed by plants, causing stunted growth and tissue death (Brown, 1990). Treatment using a mixture of triclopyr showed lower mortality symptoms compared to the treatment with methyl metsulfuron and glyphosate as active ingredients.

Treatment using the active ingredient of triclopyr was less effective in controlling epiphytic weeds compared to methyl and glyphosate treat-

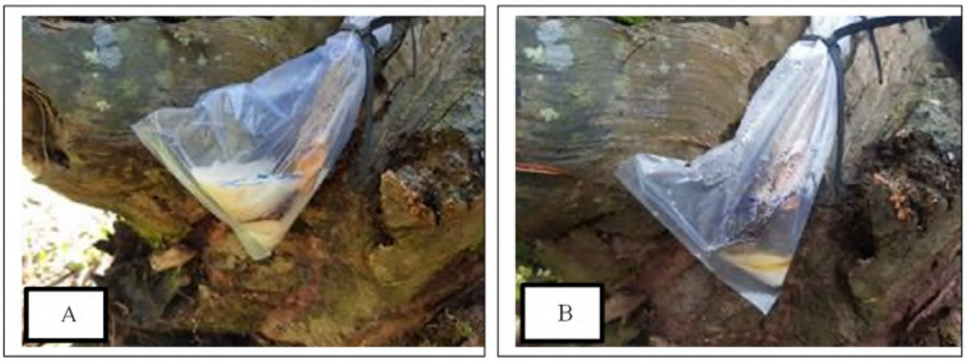

Figure 3. Absorption of methyl metsulfuron solution before (A) and after (B) an hour

Figure 4. Survived epiphytic weeds due to their roots growing towards the soil

ments, indicated by lower mortality symptoms at four weeks after application. Further research is needed to determine the appropriate concentration of triclopyr and the combination with other active ingredients for epiphytic weed control.

One of the factors increasing the chance of weed mortality using the root infusion method is the absorption of the herbicide solution tied in a plastic bag. The absorption time of the herbicide solution can occur in a short time (one to 24 hours) (Figure 3). Once the herbicide solution has been entirely absorbed, the active ingredients are translocated to all weed tissues, causing death.

Epiphytic weeds that still had other roots growing to the soil showed lower mortality symptoms compared to those whose roots had been completely cut off (Figure 4). The effect of herbicides can be less than optimal at low doses with large target plants and plant roots still having the ability to absorb water and nutrients from the soil (Hall et al., 1999). This root cutting causes the epiphytic weeds to absorb the liquid only from a mixture of herbicides in the plastic bag. Meanwhile, if other roots are not cut, the epiphytic weeds have a chance for recovery through the absorption of water and nutrients from the soil. However, the other roots are difficult to find since they are hidden between the gaps in the oil palm trunk. Epiphytic plants (banyan) are strangling plants whose roots are wrapped around the stem of the main plant. The roots grow towards the soil to absorb water and nutrients (Schmidt & Tracey, 2006).

Epiphytic weed control with the root infusion method has advantages over the spray method in terms of safety for the applicator. If control is carried out using a spray technique, the applicator has the potential to be exposed to the applied herbicide solution since the position of the weeds is at the top of the oil palm trunk. The cost comparison of the active ingredients is shown in Table 2. The most effective and economical treatment in controlling epiphytic weeds is glyphosate at a concentration of 30%. Cutting and eliminating epiphytic weeds from the oil palm tree (Nufvitarini et al., 2016) as well as spraying herbicides containing active components of Dichlobenil and Atrazine to the leaves have been reported to be effective in controlling epiphytic weeds (Bartoli et al., 1993).

CONCLUSION

Treatment of glyphosate at a concentration of 30% was the most effective and efficient treatment in controlling epiphytic weeds. Cutting the entire suction root of epiphytic weeds can increase the chance of weed mortality.

ACKNOWLEDGEMENTS

The authors would like to thank the Management of PT Bumitama Gunajaya Agro for their support in conducting this research. All authors of this article declare no conflict of interest regarding the results of this study.

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Histopathological Evaluation of Soybean (*Glycine max* (L.) Merr.) Strains Resistance to *Sclerotium rolfsii* Disease

DOI: 10.18196/pt.v10i1.8907

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ABSTRACT

Sclerotinia infection of stem and leaf of soybean *Glycine max* (L.) Merr. caused by the fungal pathogen of *Sclerotium rolfsii* has recently become more important in the Indonesian soybean production area. This study aimed to evaluate the level of resistance and intensity of infection by *S. rolfsii* in four soybean strains. The research was arranged in a factorial completely randomized design. The observed variables include the anatomy characteristics of leaves and stems of soybean and disease intensity caused by *S. rolfsii*. The data were analyzed quantitatively with the Analysis of Variance (ANOVA) at 95% and 99% confidence level, followed by the Least Significant Difference Test (Fisher's LSD) at the level of 5%. Soybean leaves and stem anatomy inoculated by *S. rolfsii* showed a decrease in the stomatal density, epidermis thickness, and mesophyll thickness as well as a damaged cuticle, damaged stem epidermis, and swollen stem cortex. Four strains inoculated by *S. rolfsii* showed a higher disease intensity of 40%-80% compared to the resistant cultivar ('Dering') and susceptible cultivar ('Wilis'), showing disease intensity of 20% and 40%, respectively.

Keywords: *Glycine max*, Histopathology, Resistance, *Sclerotium rolfsii*

ABSTRAK

Infeksi sclerotinia pada daun dan batang kedelai Glycine max (L.) Merr. yang disebabkan oleh jamur patogen Sclerotium rolfsii menjadi semakin penting di area produksi kedelai Indonesia. Penelitian ini bertujuan mengevaluasi tingkat resistensi dan tingkat intensits infeksi oleh S. roflsii terhadap empat galur kedelai. Metode yang digunakan dalam penelitian ini adalah metode eksperimen dengan pola rancangan acak lengkap pola faktorial. Parameter yang diamati meliputi karakteristik anatomi pada daun dan batang kedelai, dan intensitas penyakit yang disebabkan oleh S. rolfsii. Data dianalisis dengan Analisis Varians (ANOVA) dengan tingkat kepercayaan 95% dan 99%, analisis data dilanjutkan dengan Uji Beda Nyata Terkecil (LSD) 5%. Karakteristik histopatologi daun dan batang yang diinokulasi oleh S. rolfsii menunjukkan adanya penurunan kerapatan stomata, ketebalan epidermis dan ketebalan mesofil, sekaligus menyebabkan kerusakan pada lapisan kutikula, epidermis batang, dan pembengkakan pada korteks batang. Empat galur yang diinokulasi oleh S. rolfsii memiliki intensitas penyakit yang lebih tinggi yaitu 40% -80% dibandingkan dengan kultivar 'Dering' sebagai kelompok tahan sebesar 20% dan kelompok rentan pada kultivar 'Wilis' sebesar 40%.

Kata kunci: *Glycine max, Histopatologi, Resisten, Sclerotium rolfsii*

INTRODUCTION

Soybean (*Glycine max* L.) is an important protein source plant in Indonesia. The increase of soybean production is in line with the increase in the number of population and industrial developments using soybean as raw materials. According to Wahyu (2013), soybean is one of the widely cultivated legume commodities in Indonesia. Due to the high consumption rate, efforts are needed to increase soybean production through superior cultivars. However, efforts to increase soybean production can not be separated from various obstacles, including pest and disease attacks. One of the acute diseases is stem rot disease caused by the *Sclerotium rolfsii*.

Histopathology based on leaves anatomy characters can be used as instructions to the structural resistance of plants against the pathogen (Samiyarsih et al., 2018). *S. rolfsii* is a fungus that can cause several diseases in plants, such as stem rot. A wilting disease caused by *S. rolfsii* is a common

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Article History
Received: 28 May 2020
Accepted: 31 Jan 2022

disease in soybean plants. This disease is often also referred to as stem rot disease or sclerotium rot because it causes root rot symptoms. *S. rolfsii* can also attack leaves, stems, and pods in soybean plants if conditions are very humid. Efforts to get high-yielding soybeans can pursue through plant breeding activities. Plant breeding is expected to improve and increase plants' genetic potential so that superior results are obtained with suitable characteristics, one of which is by selecting new strains (Wardoyo, 2009). Pure strain selection is made by choosing the best plants. Selected plants are individually harvested separately for planting material the following season. Cultivar differences in plants will provide genetically different responses (Sasongko et al., 2019).

The histopathology based on plants' anatomical structure plays an essential role in the relationship with pathogenic infections in tissues. The disease's effects cannot adequately be understood without understanding the typical structure of the affected tissue. Besides, the impact of disease or parasites and even susceptibility to disease can be identified by structural changes in the host structure's characteristics. The primary response of plants affected by fungal infections is structural defenses, such as cell wall thickness. The disease can prevent the penetration of pathogens into the host cell. Besides, pathogenic infections can cause the development of plant vascular tissue structures to be disrupted (Impullitti et al., 2014).

In this research, pure soybean strains were used to determine each different soybean strain's anatomical characteristics then compared to the cultivars. This study aimed to determine the differences in the anatomical character of leaves and stems in soybean strains that are resistant and susceptible to stem rot disease after inoculation with *S. rolfsii* and the level of intensity of attacks of each soybean strain used after *S. rolfsii* fungal infection.

MATERIALS AND METHODS

The research was conducted in June-September 2019 at the greenhouse, the Plant Structure and Development Laboratory, and the Mycology and Phytopathology Laboratory, Faculty of Biology, Jenderal Soedirman University, Puwokerto. This research was arranged in a completely randomized factorial design. The first level was four soybean strains (Strain no. 71-7, 39-6, 32-6, and 16-4) and two types of soybean cultivars ('Dering' and 'Wilis'). Soybean strains and cultivars are the collections of the Faculty of Agriculture, Jenderal Soedirman University. The second level was fungal inoculation treatment. Tests without inoculation and with fungal inoculation were carried out with five replications.

The isolates of *S. rolfsii* cultures were propagated in a potato dextrose agar (PDA) medium and incubated at room temperature for 5×24 h (Astiko, 2009). Propagation of fungal inoculums was done using bran media as much as ¾ the volume of the bottle that had been sterilized first in the autoclave then inoculated with three plugs of rejuvenated fungal mycelium on PDA medium (Nugroho, 2008). The inoculation of *S. rolfsii* was carried out on the 14-day-old plant in the polybag. The inoculation of *S. rolfsii* was carried out by giving an inoculum at a depth of ± 1 cm between the plant's roots and on the soil surface.

Anatomical characteristics including cuticle, epidermis, mesophyll, stomata size, stomata, and trichomes density per mm^2 area of the epidermis of leaves were observed using embedding methods of Khoiroh et al. (2014) and Samiyarsih et al. (2020a) with a slight modification. The 5th leaf from the shoot bud was taken and cut into one-cm pieces. It was subjected to fixation in FAA solution (FAA: 10% formalin, 5% acetic acid, 50% ethyl alcohol, and 35% distilled water) for 24 h. Staining was done using safranin (1%) in 70% alcohol. Observation of anatomical characteristics was performed using a binocular microscope Olympus CH-20 (Damayanti, 2007). The incubation period was from the first day after the inoculation of pathogenic fungi until the disease's symptoms appeared. Observation of disease intensity was carried out to determine the level of resistance of soybean plants to stem rot disease. Consideration of the severity of the disease was carried out 15 days after planting. The percentage of disease intensity could be calculated using the formula of $I = N / n \times 100\%$, in which I is the severity of the disease, n is the number of plants showing symptoms, and N is the number of plants observed. Disease intensity calculation results were then categorized based on the assessment of the level of resistance (Disease intensity (%) resistance: 0-20=high; >20-30=medium, and > 30=low). All data were analyzed by ANOVA followed by Least Significant Difference (LSD) test at 0.05 (5%).

RESULTS AND DISCUSSION

Leaves Histopathological Characteristics of Soybean Strains Affected by *S. rolfsii*

The histopathology of soybean leaves that were attacked by *S. rolfsii* causing stem rot disease in the 'Dering' and 'Wilis' cultivars and four soybean strains with strain numbers 71-7; 39-6; 32-6; and 16-4 showed the similar leaf anatomical structure (Table 1; Figure 1). The plant inoculated by *S. rolfsii* was damaged in the leaf epidermis and leaf mesophyll tissue. Meanwhile, a reduced palisade density characterized damage to the mesophyll tissue, and the space between cells contained in spongy tissue or sponges had also become more extensive. The strain no. 39-6 showed the least tissue damage compared to other strains and cultivars.

The highest thickness of the epidermis was observed in strain number 39-6, with a thickness of the adaxial and abaxial epidermis of 10.1 and 9 μm, respectively. Meanwhile, the highest mesophyll thickness was found in strain number 16-4 (103.7 μm), and the lowest mesophyll thickness was in the 'Wilis' cultivar (48.6 μm). The highest number of adaxial epidermal stomata was in strain number 39-6 (5.16/mm^2), and the lowest was in strain number 16-4 (3.24/mm^2). The same results were obtained in the number of lower epidermal stomata. The highest and lowest number of lower epidermal stomata was observed in strain number 39-6 (10.16/mm^2) and strain number 16-4 (6.44/mm^2), respectively. There was significant difference in the number of adaxial and abaxial epidermal stomata (Figure 1). Kouwenberg et al. (2004) noted that morphogenesis changes caused variations in stomatal density between plants of various dicotyledonous plant species. Environmental adaptation factors can also influence the calculation of the number of stomata. Juwarno et al. (2017) reported that the adaxial and abaxial stomata density was not significantly different between soybean cultivars.

Table 1. Histopathological characteristics of leaves and stem caused by *S. rolfsii* disease

No	Cultivar/Strain	Adaxial epidermis thickness	Abaxial epidermis thickness	Mesophyll thickness	The adaxial density of stomata	The abaxial density of stomata	The abaxial density of trichomes	The abaxial density of trichomes	Stem diameter
1	Dering	9.05 c	9.30 abc	58.65 d	5.40 a	8.40 bc	5.40 a	8.40 bc	2597.4 b
2	Wilis	8.50 c	8.50 cd	57.00 d	4.92 ab	7.72 bc	4.92 ab	7.72 bc	2524.8 b
3	Strain no. 71-7	8.60 c	8.25 d	61.95 d	4.96 ab	8.36 bc	4.96 ab	8.36 bc	3089.8 a
4	Strain no. 39-6	10.50 a	10.10 a	95.90 b	5.16 ab	10.00 a	5.16 ab	10.00 a	2652.0 b
5	Strain no. 32-6	10.10 ab	9.50 ab	73.60 c	4.54 b	8.96 ab	4.54 b	8.96 ab	2483.0 b
6	Strain no. 16-4	9.25 bc	8.85 bcd	104.30 a	3.86 c	7.30 c	3.86 c	7.30 c	2496.8 b

Remarks: Values followed by the same letters are not significantly different according to LSD at 5%.

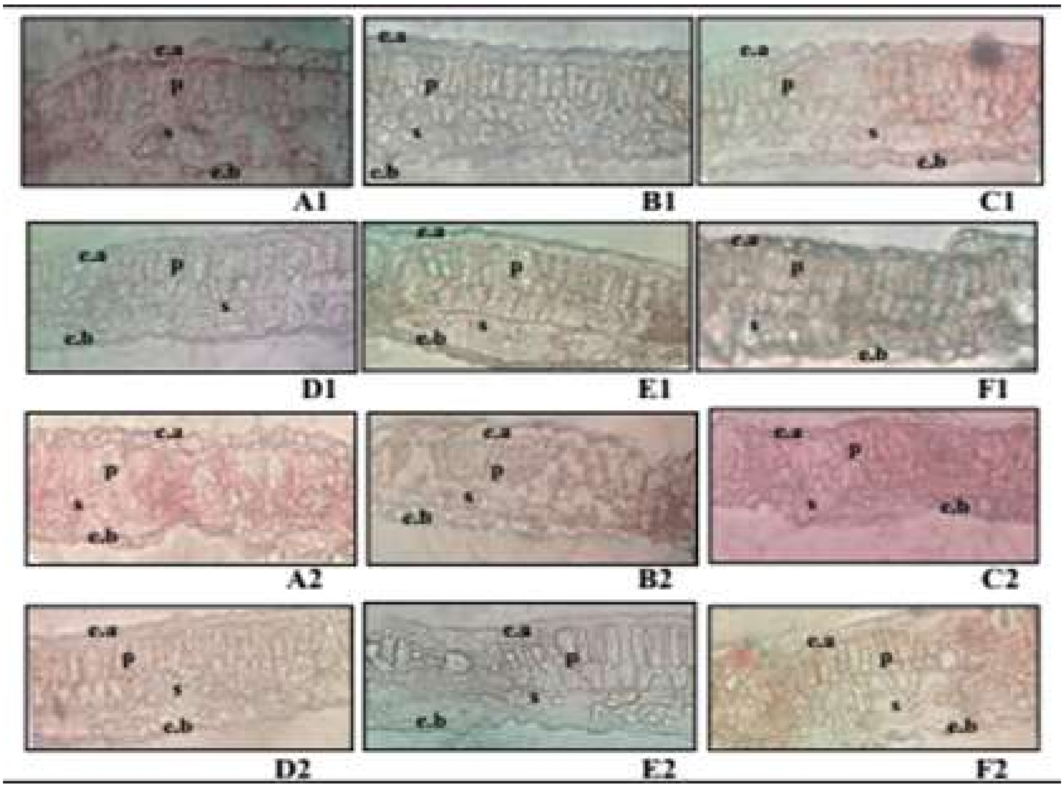

Figure 1. Leaves histopathology of soybean strains for resistance to *S. rolfsii* disease. Notes: A1-F1 (uninfected with *S. roflsii*); A2-F2 (Infected with *S.roflsii*); (A) Cultivar 'Dering'; (B) Cultivar 'Wilis'; (C) Strain no 71-7; (D) Strain no. 39-6; (E) Strain no. 32-6; (F) Strain no. 16-4; (e.a) adaxial epidermis ; (p) palisade; (s) sponges; (e.b) abaxial epidermis.

The density of trichomes indicated less intensity of leaf damage. Based on different test tables, strain no. 39-6 showed similar average number of stomata to the resistant cultivar 'Dering'. Meanwhile, strain no. 32-6 and strain no. 16-4 hade lower number of stomata compared to the susceptible cultivar 'Willis'. The average number of trichomes in the upper epidermis was less than that of the lower epidermis. Wijaya (2016) states that the difference in the number and length of trichomes on the adaxial and abaxial surfaces of leaves is influenced by plant genetic factors to prevent pests and diseases that usually attack through the underside of the leaves. Arifin (2013) adds that the number of trichomes in healthy soybean plants is higher more than in sick soybean plants. Pradana et al. (2017) reported that the density of stomata-trichomes was the same as the plant disease intensity. On the other hand, Samiyarsih et al. (2020b) mention that soybean cultivars that have thicker cuticle and epidermis, high trichomes and low stomatal density, and low stomatal conductance have better anatomical resistance to leaf rust disease.

The lowest thickness of the upper epidermis was found in the 'Wilis' cultivar (5.8 µm), but the lowest epidermis thickness was observed in the strain 71-7 (6 µm). Decreased epidermal thickness is thought to occur as a result of changes in cell permeability in response to pathogens. Sastrahidayat (1989) summarized that reduced cell permeability was the beginning of changes in diseased tissue. The cells in the tissue that is attacked and damaged often undergo plasmolysis. Besides, the decrease in plants' epidermal thickness inoculated with *S. rolfsii* can also be caused by chemicals during preparations. Diseased plant tissue is more easily damaged when given treatment using chemicals. According to Samiyarsih et al. (2018), disease-resistant plants

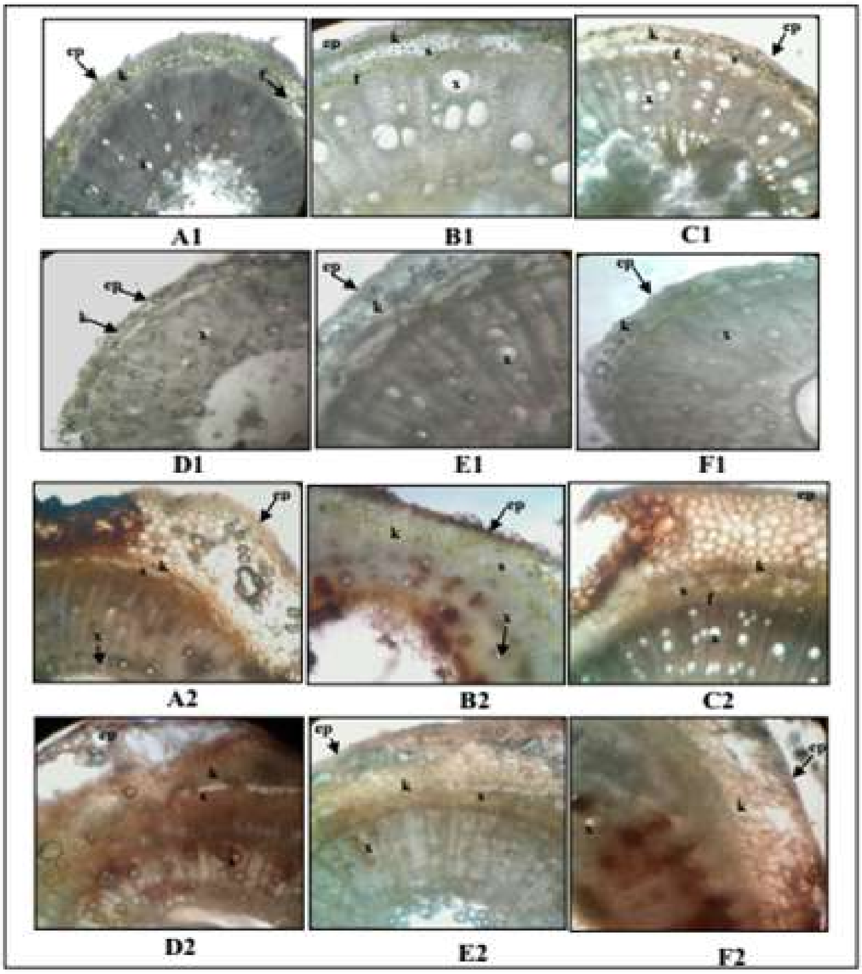

Figure 2. Stems histopathology of soybean strains for resistance to *S. rolfsii* disease. Notes: A1-F1 (uninfected with *S. roflsii*); A2-F2 (Infected with *S.roflsi*); (A) Cultivar 'Dering'; (B) Cultivar 'Wilis'; (C) Strain no 71-7; (D) Strain no. 39-6; (E) Strain no. 32-6; (F) Strain no. 16-4; (e.a) adaxial epidermis ; (p) palisade; (s) sponges; (e.b) abaxial epidermis.

tend to have thick epidermis, playing an essential role in inhibiting pathogens penetration into host cells.

Stem Diameter of Soybean Strains Affected by *S. rolfsii*

Strain number 71-7 were significantly different from the cultivar 'Dering,' cultivar 'Wilis,' strain number 39-6, strain number 32-6, and strain no. 16-4. Other than strain numbers 71-7, the other strains and cultivars had uniform stem size (Figure 2). Stems infected with *S. rolfsii* showed a more brownish color. The color is due to the attacks of *S. rolfsii* to the stem's base, causing the bottom of the stem to be swollen before finally decaying. Phenol accumulation also occurs, causing the stem to turn brown. Changes in metabolism in diseased plants accompany an increase in respiration after infection because the enzymes associated with respiration increase. Tang et al. (2015) reported that *S. rolfsii* produced a variety of extracellular enzymes, including pectin methylesterase, cutaneous, phosphatides, arabanase, gateringase, mannanase, xylanase, oxalic acid, and polygalacturonase, which are thought to cause tissue death along with mycelial growth during the infectious process.

The stem diameter of the cultivar 'Dering' inoculated with *S. rolfsii* had a larger size than that

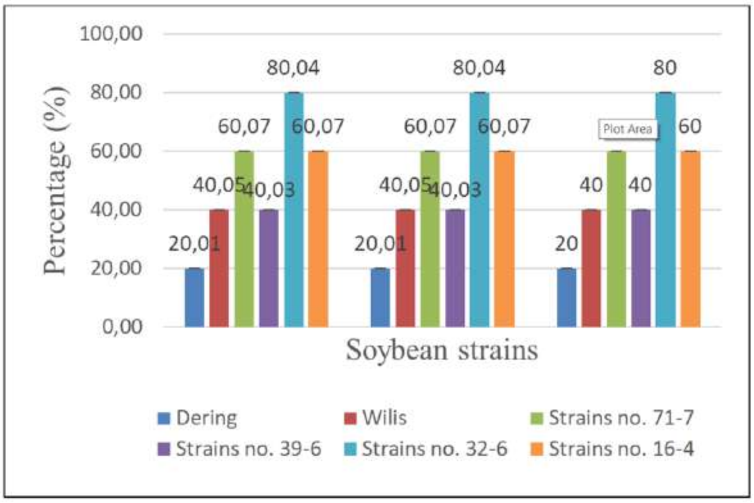

Figure 3. Percentage of disease intensity of soybean strains against S. rolfsii (in three replication).

of the cultivar 'Dering' without inoculation. This is related to the swollen stems of plants after the inoculation of *S. rolfsii*. It was characterized by an enlarged size of the cortex of stems infected with *S. rolfsii* due to disruption of nutrient absorption by xylem and phloem compared to stems uninfected with *S. rolfsii*. The cortex's internal part is a system of stem vessels consisting of the phloem on the outside and xylem. Another factor that is thought to have an influence is the swollen cell wall, which increases diameter. Direct penetration occurs in the epidermis cell wall by a pathogen, and sometimes the outer cell wall will be swollen, thereby inhibiting pathogen penetration. The results of the analysis of the variety of soybean stem diameters showed very significant values. Pranita et al. (2010) investigated that in stems experiencing secondary growth, the epidermal layer is replaced by a cork layer formed from cork cambium. The cork layer in plants helps increase the protective power of the stem and reduce water evaporation.

Pathogenicity of *S. rolfsii* to soybean strains and cultivars

The pathogenicity test results on soybean revealed that *S.rolfsii* fungi were capable of infecting test plants, including the 'Dering' cultivar, 'Wilis' cultivar, strain no. 71-7, strain no. 39-6, strain no. 32-6, and strain no. 16-4. 'Dering' cultivar showed the lowest disease intensity value of 20%. 'Wilis' cultivar and line no. 39-6 had the same disease intensity value, equal to 40%, and strain no. 71-7 showed a disease intensity of 60%. Meanwhile, the highest disease intensity was found in strain-no—32-6, which is 80% (Figure 3). The disease intensity of 'Dering' cultivar showed a high level of disease resistance. Meanwhile, the 'Wilis,' *S. rolfsii* cultivar, strain no. 71-7, strain no. 39-6, line 32-6, and line no. 16-4 are categorized as low resistance.

In soybean plants, the symptom is the start of the withering of soybean plants, accompanied by the stems' base that begins to rot. The incubation period for *S. rolfsii* pathogens in test plants ranged from three to nine days. Environmental factors provide a considerable influence for pathogens to infect soybean plants. Environmental conditions due to routine watering in the morning and evening cause the soil around the stems to become more humid. This is undoubtedly beneficial for the breeding of *S. rolfsii* spores. Sumartini (2011) reported that the *S. rolfsii* would be more infective at high humidity, causing high intensity and extent of the attack. Conversely, low moisture would stimulate *S. rolfsii* to form sclerotia.

The novelty of selecting soybean germplasm against biotrophic fungal disease is essential and effective in order to increase crop productivity (Samiyarsih et al., 2020b). Overall, the level of resistance in the four strains observed is relatively low. This is due to the high intensity of disease in the four strains compared to cultivars that have been released, which is above 30%. The higher the intensity of the disease, the lower the resistance to pathogens. Astiko et al. (2009) stated that there were differences in resilience plants among soybean varieties in suppressing the development of rot disease stem base. Each strain has different resistance characteristics to *S. rolfsii* attacks due to the different resistance genes controllers to fight pathogens in each variety.

CONCLUSION

The difference in disease intensity of soybean strains and cultivars tested is greatly influenced by plant resistance. Histopathological evaluation of soybean leaves inoculated by *S. rolfsii* showed decreased leaf epidermis thickness and leaf mesophyll thickness, as well as damage to the cuticles, stem epidermis, and swollen cortex of the stem. All Strains inoculated with *S. rolfsii* showed a higher disease intensity of 40% -80% compared to the resistant cultivar 'Dering' (20%), and the susceptible cultivar 'Willis' (40%). This method is helpful in differentiating reactions of soybean strain or cultivars to *S. rolfsii*.

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The Role of Indigenous Mycorrhizae of Corn Plants in Various Soil Types in Gunung Kidul, Indonesia

DOI: 10.18196/pt.v10i1.11428

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ABSTRACT

Indigenous Vesicular-Arbuscular Mycorrhizae (VAM) are natural mycorrhizae from specific areas that have good environmental adaptability. This study, conducted from January to November 2020 at the Faculty of Agriculture, Universitas Gadjah Mada, aimed to isolate the vesicular-arbuscular mycorrhizal fungus so that it can be used as information on the type and role of VAM on Gunung Kidul soil. The research was arranged in a Completely Randomized Design (CRD) with three factors. The first factor was soil type from Gunung Kidul Regency (Inceptisol, Mollisol, and Alfisol), the second factor was sterilization (sterilized soil and unsterilized soil), and the third factor was corn variety (local and hybrid). Analysis of soil and plant growth was performed by using Analysis of Variance (ANOVA) and Tukey's Honestly Significant Difference (Tukey's HSD) Test. Genetic detection of root infecting VAM was performed by using Terminal Restriction Fragment Length Polymorphism (T-RFLP) method with FAM AML1-AML2 labeled primers. The VAM detected in the roots of hybrid variety included *Acaulospora* sp., *Gigaspora* sp., and *Septoglomus* sp., and those in the roots of local variety were *Acaulospora* sp., *Gigaspora* sp., and *Funelisformis* sp. The results showed that the role of VAM could be seen through unsterilized soil so that there was no VAM elimination in the soil. Unsterilized soil showed the best results of root infection, leaf fresh and dry weight, leaf phosphor (P) content, and leaf P uptake. Meanwhile, Alfisol showed the best result of root infection, fresh weight, dry weight, leaf P content, and leaf P uptake. The treatment of plant varieties showed that the varieties did not significantly affect the root infection, fresh weight, dry weight, leaf P content, and leaf P uptake.

Keywords: Corn variety, Indigenous mycorrhiza, Soil, Sterilization,

ABSTRAK

Mikoriza arbuskular vesicular(VAM) indigenous adalah mikoriza alami unggul dari wilayah spesifik yang memiliki daya adaptasi lingkungan yang baik. Penelitian ini, yang dilakukan pada Januari-November 2020 di Fakultas Pertanian Universitas Gadjah Mada bertujuan untuk mengisolasi cendawan Mikoriza vesikular arbuskular sehingga dapat digunakan sebagai informasi jenis serta peran VAM pada 3 tanah Gunung Kidul, Metode penelitian menggunakan Rancangan Acak Lengkap 3 Faktor. Faktor pertama Jenis Tanah terdiri atas Inceptisol, Mollisol, Alfisol. Faktor kedua adalah Jenis Sterilisasi terdiri atas tanah steril dan tanah tanpa steril. Faktor ketiga Jenis Varietas, terdiri atas varietas lokal dan hibrida. Analisis data parameter tanah dan tanaman menggunakan Analisis Varians (ANOVA) dengan Uji Beda Nyata Jujur (HSD Tukey). Pendeteksian genetik Mikoriza penginfeksi akar menggunakan metode Terminal Restriction Fragment Length Polymorphism (T-RFLP) dengan primer berlabel FAM AML1-AML2. Mikoriza vesicular arbuskular yang terdeteksi pada akar varietas hibrida antara lain Acaulospora sp., Gigaspora sp., dan Septoglomus sp., kemudian pada akar varietas lokal adalah Acaulospora sp., Gigaspora sp., dan Funelisformis sp. Peran VAM dapat dilihat melalui tanah yang tidak steril sehingga tidak terjadi eliminasi VAM di dalam tanah. Tanah yang tidak disterilkan menunjukkan hasil infeksi akar terbaik, berat segar dan kering daun, kandungan fosfor (P) daun, dan serapan P daun. Perlakuan jenis tanah menunjukkan bahwa Alfisol menunjukkan hasil infeksi akar, bobot segar, bobot kering, kandungan P daun, dan serapan P daun yang paling baik. Varietas tidak berpengaruh nyata terhadap hasil infeksi akar, bobot segar, bobot kering, kandungan P daun, dan serapan P daun terbaik.

Kata kunci: *Mikoriza indigenous, Tanah, Sterilisasi, Varietas jagung*

INTRODUCTION

Gunung Kidul is an area with carcass as a parent material with several soil orders formed on it. Some examples of soil orders with soil development rates include young soils, such as Inceptisols, Alfisols, and Mollisols. According to Abdurachman et al. (2008), Inceptisols with dry land in hilly areas (15-30%) generally have low soil fertility, steep slopes, and shallow solum. Meanwhile, Alfisol has the characteristics of an argillic horizon, relatively easily weathered minerals, and alkaline saturation > 3% at a depth of 180 cm from the soil surface or 125 below the upper limit of the argillic horizon. Mollisols are soils that are generally deep soluble, dark in color, and rich in bases, and the alkaline

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Article History
Received: 05 Apr 2021
Accepted: 25 Jan 2022

saturation is > 50% in Mollisols whose solum is> 1 m (Rachim, 2007).

Soils formed above the karst environment cause frequent drought in the Gunung Kidul area. This is because the carcass structure causes the water retention capacity to be very low. Low water retention capacity during the dry season will affect plant growth and production. Dry soil will have a dense texture, inhibiting the absorption of water and nutrients in plants. Dense soil is also less favorable for plant growth because root growth and penetration will be limited and also has a low percentage of pores and aeration. The plant growth and production are affected by soil fertility, including physical, chemical, and biological properties of the soil. Soil biological property is a determining factor of soil quality due to the symbiosis between soil microorganisms and plants. One of the well-known soil microorganisms to have a great defense system in extreme conditions supporting dryland farming is Arbuscular Mycorrhizae.

Vesicular-Arbuscular Mycorrhizal is microorganism of the fungal group. According to Aguzaen (2009), VAM can have a mutualistic symbiosis with higher plants. The external hyphae of mycorrhizal fungi, which are longer and finer than root hairs, can expand the surface area of root absorption. This would increase nutrient and water uptake, especially in critical soil conditions. Bukovská et al. (2018), in their research, stated that VAM could significantly contribute to nitrogen (N) absorption from complex organic sources. The plants in which VAM grew were 6.4 times larger, accumulating 15 N derived from organic labeled sources 20.3 times higher compared to non-VAM plants. Praharasti et al. (2012), in their research, stated that VAM could increase the growth and productivity of plants such as corn.

The results of research by Alguacil et al. (2016) showed that VAM had associations with soil rhizosphere and root habitats. Soil type also determines the distribution of VAM communities in the soil, and this effect cannot be attributed to a single soil characteristic. This is because at least three soil properties are related to microbial activity, namely pH and levels of two nutrients (Mn and Zn) that play an important role in triggering the VAM population. The pH value affects the ability of spores to germinate, and micronutrients, such as Mn and Zn, are essential nutrients for plant metabolism.

The results of research by Oehl et al. (2010) showed that soil characteristics (soil type and pH) were more important in regulating the composition of VAM species. Several VAM species appear to be specialists in existence. For instance, Pacispora in that study was generally absent in Inceptisol and was never found at pH <6.0. His research concluded that there were many differences in VAM species in the observed differences in soil types. However, the land-use intensity had a greater impact on the VAM population and species composition than the soil type did.

Vesicular-arbuscular mycorrhizae form a mutualism symbiosis in most plant roots. This symbiosis is of great relevance to sustainable agriculture because of its ability to increase productivity, nutrient uptake (Carballar-Hernandez et al., 2018), soil aggregation, and crop protection. Endophytic and symbiotic VAM directly interact with live host plants. Corn plants are usually associated with VAM because their root system supports the fungi's growth, and corn plants supply carbon in exchange for nutrients, especially phosphorus.

Therefore, understanding the community and the abundance of VAM in soil types in the karst environment, which are identical to drought, is necessary. Vesicular-arbuscular mycorrhizae are detected using the T-RFLP technique. This technique is used to determine the diversity, structure, and dynamics of the microbial community of an environment. This technique is often used because of the production and analysis of data that is accurate, fast, and effective in differentiating microbial communities (Kitts, 2001). The advantages of the T-FRLP technique compared to other techniques are that it provides the same replication, higher resolution, and is more sensitive (Osborn et al., 2000). The information can be used to develop appropriate management strategies, thus, optimizing the role of VAM in achieving sustainable agriculture. Astuti et al. (2017) have identified the indigenous Mediterranean VAM in Gunung Kidul using the trapping method. They found the type of *Glomus* sp. and tested its effectiveness on the growth of cassava plants including root length, plant height and plant dry weight. Thus, this study aimed to determine the role of indigenous vesicular-arbuscular mycorrhizal (VAM) and root infection by VAM on nutrient uptake and plant development.

MATERIALS AND METHODS

Time and Location of the Research

There were three types of soil used in this study, including Mollisol and Inceptisol obtained from Tahura Bunder Gunung Kidul and Alfisol from the Mulo area, Gunung Kidul. This research was conducted from January to November 2020. Vesicular-arbuscular mycorrhizae's DNA and soil analysis were carried out at the Laboratory of Microbiology and Soil Science of the Faculty of Agriculture UGM. Other materials included hybrid (Bisi 18) and local (Guluk-guluk) corn varieties. Basic fertilizers used were urea 300 kg / ha (0.75 g / polybag), KCl 100 kg / ha (0.25 g / polybag) (Isrun, 2006), and rock phosphate 300 kg / ha (0.75 g / polybag) (Wahyudin et al., 2017).

Experimental Design and Data Collection

The experimental design applied was a completely randomized design with three treatment factors. The first factor was soil type (T) (Inceptisol (T1), Mollisol (T2), and Alfisol (T3)), the second factor was soil sterilization (S) (with soil sterilization (S1) and without soil sterilization (S2)), and the third factor was corn Varieties (V) (local (V1) and Bisi 18 hybrid (V2) variety).

The planting media were prepared by sieving the soils, which then were separated into two parts. The first part of the soil was sterilized, and the second one was not sterilized. The method of sterilization was formaldehyde sterilization with a cover. The soil was put in a bucket, given 2% formaldehyde at a dose of 2 l / ft2, given water to field capacity, and then incubated by covering it with plastic for seven days. The soil was then drained and air-dried for three weeks before planting (Cahyani, 2009; Lawrence, 1956). The variables observed were the percentage of mycorrhizal infections, plant height, plant fresh and dry weight, leaf P, plant nutrient P uptake, and mycorrhizal species diversity.

Root infection was observed by taking small roots with good morphology taken as samples collected in plastic bags that can be sealed and then stored at a temperature of – 4 °C until further processing (Boeraeve et al., 2019). The VAM's DNA in the roots was extracted by taking 0.5 g of fine corn roots, which were then crushed with liquid nitrogen then continued with the CTAB isolation method (Doyle and Doyle, 1990; Khan et al., 2007). The next stage, namely DNA amplification, was performed by filling the PCR tube using 25 microliters of the PCR reaction mixture for T-RFLP using a PCR thermocycler machine for 40 cycles, then optimizing the temperature during annealing. The primer pairs used for the T-RFLP annealing stage were AML1 (ATCAACTTTCGATGGTAGGATAGA) labeled FAM and AML2 (GAACCCAAACACTTTGGTTTCC) (Desah and Widada, 2014). The first and second denaturation, annealing process, extension process, and the final extension was performed at a temperature of 95 °C for two minutes, 95 °C for 30 seconds, 55.9 °C for 30 seconds, 72 °C for a minute, and 72 °C for five minutes, respectively. Visualization of T-RFLP DNA amplification results was viewed by gel electrophoresis using agarose. After the DNA bands were visible on the - / + 800 base pairs column, then the T-RFLP amplified DNA was cut using the restriction enzyme MspI (5'- CC ^ GG-3 ') by mixing all the reagents to be incubated at 37 °C for three hours and continued to the fragment analysis stage.

Statistical Analysis

Data from the analysis of soil and plant growth were analyzed using analysis of variance (ANOVA), continued with Tukey's test (HSD) to find out the significant differences between treatments. Data from laboratory analysis in the form of T-RFLP were collected from the database available at NCBI. From the collected data, fragments of each species were cut with NEB cutter at neb.com. The species found were matched from each peak formed during the fragment analysis.

In this study, Inceptisol had a sandy clay loam texture, consisting of 52.41% sand, 22.43% silt, and 25.16% clay (Table 1). The Inceptisol soil before sterilization was slightly alkaline (pH H_2O of 7.73), while after being sterilized, the value of pH H_20 was 7.44 (neutral). This result is due to the content of $CaCO_3$, which is the dominant constituent of the parent material of limestone. The CO_3^{2-} ion dissociating from $CaCO_3$ in the water system would hydrolyze the water, thereby releasing OH^- into the soil solution and increasing the pH (Hanudin et al., 2012).

The CEC value of the Inceptisol soil, both before and after being sterilized, was in the high category (34.37 and 33.83 [Cmol (+).kg-1], respectively). Soils that have higher clay/colloid content and/or higher organic matter content have a higher CEC than soils that have low clay and organic matter content (sandy soil), as well as the soils that have low organic matter content. CEC value is also influenced by the clay type. The soil with a clay type of 2: 1 (montmorillonite) will have a higher CEC compared to that with a clay type of 1: 1 (kaolinite) or 2: 1: 1 (chlorite) (Winarso, 2005).

RESULTS AND DISCUSSION

Table 1. Chemical and physical properties of Inceptisol soil in Gunung Kidul

Parameter	Unit	Unsterilized Inceptisol		Sterilized Inceptisol	
		Value	Category	Value	Category
Texture					
Sand	%	52.41	Sandy clay loam		
Silt	%	22.43			
Clay	%	25.16			
pH H2O	-	7.73	Slightly alkaline	7.44	Neutral
CEC	[Cmol (+).kg-1]	34.37	High	33.83	High
Organic C	%	2.33	Medium	2.24	Medium
Total N	%	0.94	Extremely high	0.75	Extremely Low
NH4+	%	0.01	-	0.01	-
NO3-	%	0.01	-	0.01	-
Available P	ppm	0.74	Extremely low	0.74	Extremely low
Total P (bray)	ppm	3.68	Extremely low	4.14	Extremely low
Available K	[Cmol (+).kg-1]	0.40	Medium	0.54	Medium
Available Na	[Cmol (+).kg-1]	0.59	Medium	0.53	Medium
Available Ca	[Cmol (+).kg-1]	7.59	Medium	7.68	Medium
Available Mg	[Cmol (+).kg-1]	1.59	Medium	1.64	Medium

Table 2. Chemical and physical properties of Mollisol soil in Gunung Kidul

Parameter	Unit	Unsterilized Mollisol		Sterilized Mollisol	
		Value	Category	Value	Category
Texture					
Sand	%	10.35			
Silt	%	27.08	Clay		
Clay	%	62.57			
pH H2O	-	6.81	Neutral	6.42	Slightly acidic
CEC	[Cmol (+).kg-1]	27.72	High	29.06	High
Organic C	%	4.35	High	4.76	High
Total N	%	2.64	Extremely high	2.45	Extremely high
NH4+	%	0.01		0.01	-
NO3-	%	0.01		0.01	-
Available P	ppm	0.46	Extremely low	0.67	Extremely low
Total P	ppm	3.88	Extremely low	3.22	Extremely low
Available K	[Cmol (+).kg-1]	0.12	Low	0.24	Low
Available Na	[Cmol (+).kg-1]	0.30	Low	0.38	Low
Available Ca	[Cmol (+).kg-1]	4.85	Low	4.81	Low
Available Mg	[Cmol (+).kg-1]	1.94	Medium	1.96	Medium

The organic C content of the Inceptisol soil in this study was in the medium category, both before and after the sterilization process, with a value of 2.33 and 2.24%, respectively. Organic matter can improve the chemical, physical, and biological properties of the soil, which have irreplaceable functions. Meanwhile, the total N of the Inceptisol soil, before and after being sterilized, was in the extremely high category, with a value of 0.94 and 0.75%, consecutively. The NH_4^+ and NO_3^- content before and after sterilization were 0.01 and 0.01% and 0.01 and 0.01%, respectively. Meanwhile, the available P and total P of the Inceptisol soil were extremely low. This result could happen because the P element is fixed or retained by base cations such as Ca. Thus, its availability can be very low (Carreira et al., 2006). The total P and available P of the Inceptisol soil before and after sterilization were 3.68 and 4.14 ppm and 0.74 and 0.74 ppm, consecutively.

All of the alkaline cations (K, Ca, Na, and Mg) of the Inceptisol soil in this study, both before and after the sterilization process, were in the medium category. The available K of the Inceptisol soil before and after the sterilization process was 0.399 and 0.54 [Cmol (+).Kg-1], respectively. Meanwhile, the available Ca before and after the sterilization process was 7.59 and 7.68 [Cmol (+). kg-1], consecutively. On the soils developing from base parent materials with soil development that is not classified as old soils, Ca becomes a cation dominating the 70-90% exchange complex of the land exchange site (Winarso, 2005). This is in line with the Ca of the Inceptisol soil in this study, which was in the medium category (7.59 and 7.68 [Cmol (+). kg-1]), showing the highest percentage value of other cations. Meanwhile, the available Na was 0.59 and 0.53 [Cmol (+).kg-1], and the available Mg was 1.59 and 1.64 [Cmol (+).kg-1].

Based on the results of the initial soil analysis (Table 2), the Mollisol soil in this study had a clay texture, with a percentage of 10.35% sand, 27.08% silt, and 62.57% clay. The value of pH H_2O was 6.81. Based on the category set by Balai Penelitian Tanah (2009), the pH value was in the neutral category, and after sterilization, the pH of H_2O changed to 6.42, which is slightly acidic. The CEC of the mollisol soil in this study both before or after sterilization was categorized in the high category (27.72 and 29.06 [Cmol (+).kg-1]). Organic C of the mollisol soil before and after sterilization was 4.35 and 4.76%, respectively, categorized in the

Table 3. Chemical and physical properties of Alfisol soil in Gunung Kidul

Parameter	Unit	Unsterilized Alfisol		Sterilized Alfisol	
		Value	Category	Value	Category
Texture					
Sand	%	6.65			
Silt	%	68.93	Silt loam		
Clay	%	24.42			
pH H2O	-	6.53	Acidic	6.50	Acidic
CEC	[Cmol (+).kg-1]	27.16	High	28.96	High
Organic C	%	3.63	High	3.68	High
Total N	%	1.79	Extremely high	1.74	Extremely high
NH4+	%	0.01	-	0.02	-
NO3-	%	0.01	-	0.01	-
Available P (olsen)	ppm	0.65	Extremely low	0.97	Extremely low
Total P (bray)	ppm	7.32	Low	7.40	Low
Available K	[Cmol (+).kg-1]	0.24	Low	0.29	Low
Available Na	[Cmol (+).kg-1]	0.20	Low	0.24	Low
Available Ca	[Cmol (+).kg-1]	3.61	Low	3.67	Low
Available Mg	[Cmol (+).kg-1]	1.51	Medium	1.59	Medium

high category. The nitrogen element in mollisol soil was analyzed for either total N or NH_4^+ and NO_3^-. The mollisol in this study had a very high total N value both before and after sterilization, namely 2.64 and 2.45%, respectively. Meanwhile, before and after sterilization, the content of NH_4^+ was 0.01 and 0.01%, respectively, and NO_3^- was 0.01 and 0.01%, consecutively.

The alkaline cations (K, Na, Ca, and Mg) of the mollisol soil in this study were also tested. The content of available K before and after sterilization was 0.12 and 0.24 [Cmol (+). kg-1], respectively, categorized in the low category. Na content was 0.30 and 0.38 [Cmol (+). kg-1], categorized in the low category. The content of Ca was 4.85 and 4.81 [Cmol (+). kg-1], categorized in the low category. Meanwhile, the Mg content Mg was 1.94 and 1.96 [Cmol (+). kg-1], categorized in the medium category (Balai Penelitian Tanah, 2009).

The Alfisol soil in this study had a silt loam texture, consisting of 6.65% sand, 68.93% silt, and 24.42% clay (Table 3). Soil reaction (soil pH) is a term used to describe acid-base reactions in the soil. The pH H_2O of the sterilized and unsterilized Alfisol soil in this study was 6.53 and 6.50, respectively, categorized as acidic according to Balai Penelitian Tanah (2009). Cation exchange capacity (CEC) is the ability of the soil to absorb and exchange cations. The CEC of Alfisol soil in this study before and after sterilization was 27.16 and 28.96 [Cmol (+) kg-1], consecutively, categorized in the high category. The greater the value of the CEC, the greater the power of cation exchange in the soil. Several factors affecting the CEC are the amount of clay, the type of clay minerals, and organic matter content since organic matter can increase the negative charge (Darlita et al., 2017).

Soil organic matter can be determined by measuring the level of organic carbon in the soil. The organic matter content of Alfisol before and after sterilization was 3.63% and 3.68%, respectively, categorized in the high category (Balai Penelitian Tanah, 2009).

Nitrogen is an essential macro element for plant growth due to its function to increase chlorophyll content that plays an important role in the photosynthesis process. The N content of the sterilized and unsterilized Alfisol soil in this study was 1.79% and 1.74%, respectively, categorized in the very high category (Balai Penelitian Tanah, 2009).

Phosphorus is an essential macro element closely related to plant growth due to its irreplaceable roles in plants. Phosphorus is mostly absorbed by plants in the form of primary orthophosphate ions ($H_2PO_4^-$). Meanwhile, its small amount is absorbed in the form of secondary orthophosphate ions (HPO_4^{2-}). Phosphorus plays an essential role in photosynthesis, respiration and energy transfer and storage, cell division, and enlargement. The total P content of Alfisol soil in this study before and after sterilization was 7.32 ppm and 7.40 ppm, consecutively, categorized in the low category. Meanwhile, the available P of the soil before and after sterilization was 0.65 ppm and 0.97 ppm, respectively (very low) (Balai Penelitian Tanah, 2009).

K, Ca, Na, and Mg elements are types of alkaline cations adsorbed by the soil. The available K before and after sterilization was 0.24 and 0.29 [Cmol (+).kg-1], respectively, categorized in the low category. Na, as one of the basic cations, is an element from mineral leaching in the soil usually absorbed by plants in the form of Na^{2+}. The available Na was low, both before and after sterilization, at a value of 0.20 [Cmol (+).kg-1] and 0.24 [Cmol (+).kg-1], consecutively. The available Ca content in the soil is strongly influenced by the soil parent material. Soils containing limestone source rock tend to have higher Ca levels. However, Ca levels will generally decrease as the soil depth decreases. This is because the soil is getting away from the parent material rich in $CaCO_3$ (Hanudin et al., 2012). The available Ca in Alfisol in this study was low, which was 3.61 and 3.67 cmol (+).kg-1] before and after sterilization, respectively. The low available Ca as a base cation in Alfisol in this study correlates with the acidic soil conditions. The available Mg was in the medium category, both before and after sterilization, namely 1.51 and 1.59 cmol (+).kg-1). Magnesium in the soil can come from weathering rocks that contain Mg. The main source of Mg for plants is from soil solutions and the sorption complex. Magnesium can be absorbed by plants in the form of Mg^{2+} cations.

Root Infection

Based on the ANOVA results (Table 4), there was an interaction effect of soil type and sterilization on the root infection. The Alfisol soil without sterilization showed the highest root infection of 89.44 (%) compared to other treatments. The effect of soil sterilization using formaldehyde showed a decrease in the percentage of root infections. However, infected roots were still found after sterilization with formaldehyde, indicating that there were strains resistant to formalin (Hayman, 1970). Hu et al. (2020) mention that sterilization reduces colonization to less than 0.1% as well as decreases the germination rate and survival rate

Table 4. Effects of soil types and sterilization on the root infection

Soil types	Sterilization		Mean (%)
	S1	S2	
Inceptisol	6.11 c	60.92 b	33.52
Mollisol	1.67 c	56.66 b	29.17
Alfisol	3.33 c	89.44 a	46.39
	3.70	69.01	(+)

Remarks: Values followed by the same letters in the same column are not significantly different according to Tukey's test (HSD) at 5 %.

Table 5. Effects of corn plant varieties on the root infection

Corn plant varieties	Mean (%)
Local variety	35.56 a
Hybrid variety	37.16 a

Remarks: Values followed by the same letters in the same column are not significantly different according to Tukey's test (HSD) at 5 %.

of VAM. The high percentage of VAM infections is also caused by the P content that is not high. It causes a balanced mutualism symbiosis between VAM and plants. The low P content in the soil establishes a good symbiosis between VAM and plants. Vesicular-arbuscular mycorrhizae help translocate P from the soil to plants, while plants would provide carbohydrates for VAM growth (Bao et al., 2019); Correa et al., 2012). In contrast, Jasper et al. (1979) stated that in general, plants rich in P lacked carbohydrates, thereby reducing VAM colonization.

Based on ANOVA analysis (Table 5), there was no significant effect of the corn plant varieties on the root infection. The root infections in the local and hybrid corn varieties were 35.56% and 37.158%, respectively. The treatment of varieties was not significant for root infection because the exudate produced could be the same amount. This is in accordance with research by Nursyamsi (2009), reporting that the average root exudate was not significantly different between corn varieties. Root exudates would appear significantly different at different stages of plant growth. Mc. Cully (1989) in Carrenho et al. (2007) states that exudates are important because root infection occurs when plants emit a signal in the form of root exudates to invite VAM to germinate and penetrate into plant roots.

Plant Height

Figure 1 shows the observation data of the corn plant height every week from one to six weeks after planting. It illustrates that the corn plant height observed once every seven days appears to increase every week. The observation was performed for six weeks (until the stage of maximum vegetative

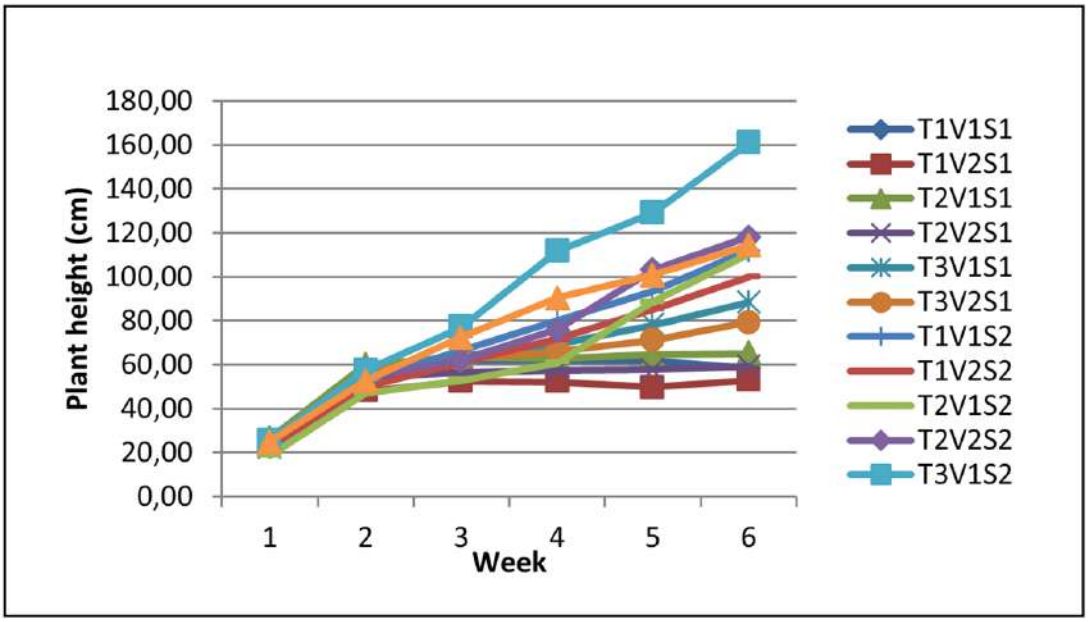

Figure 1. Effects of soil types, corn varieties, and soil sterilization on the corn plant height

growth).

Based on Figure 1, each treatment showed varied average plant height each week. The treatment resulting in the highest plant height was T3V1S2 (Alfisol, local corn variety, unsterilized soil). Meanwhile, the lowest plant height was found in the T1V2S1 treatment (Inceptisol, hybrid corn variety, sterilized soil). The T3V1S2 treatment resulted in the highest plant height because, in this treatment, the Alfisol soil was not sterilized. This result can also be attributed to the presence of high VAM in the Alfisol soil compared to other soil types.

Ortas et al. (2018) state that plant height growth is influenced by unsterilized soil due to the indigenous VAM infecting the roots so that plants can grow well. Sterilized soil would kill all indigenous VAP so that plants growing on sterile soil conditions do not grow well compared to those growing on non-sterile soils. Ortas (2012) and Ortas et al. (2002) showed that, without the presence of VAM, plants grew better on unsterilized soils than on sterilized soils, which could be attributed to the effectiveness of indigenous VAM.

Leaf Fresh Weight

Fresh weight is one of the parameters that represent the growth of a plant. The leaf fresh weight is the fresh weight of the leaf after harvest before

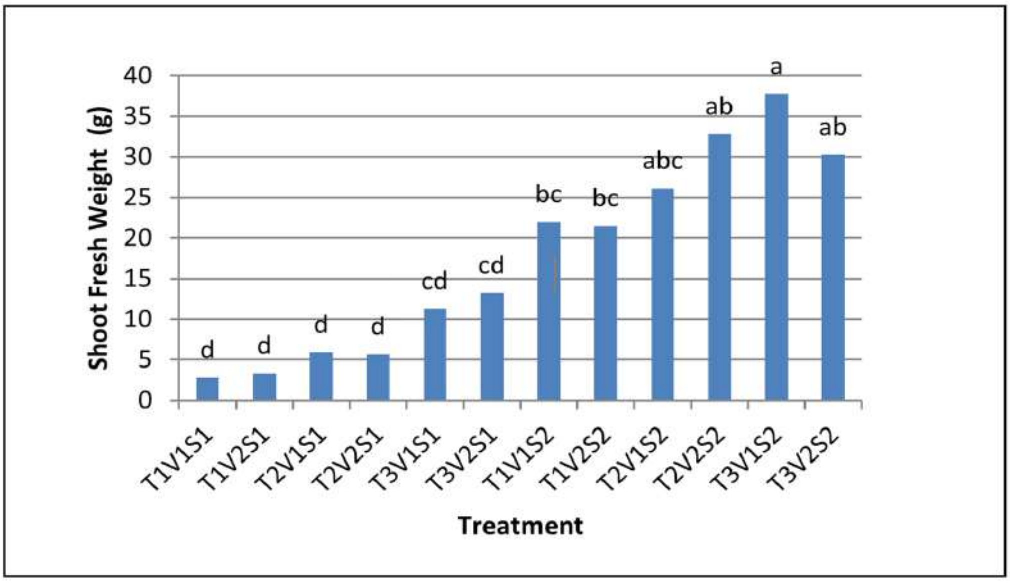

Figure 2. Effect of soil types, corn varieties, and soil sterilization on the leaf fresh weight

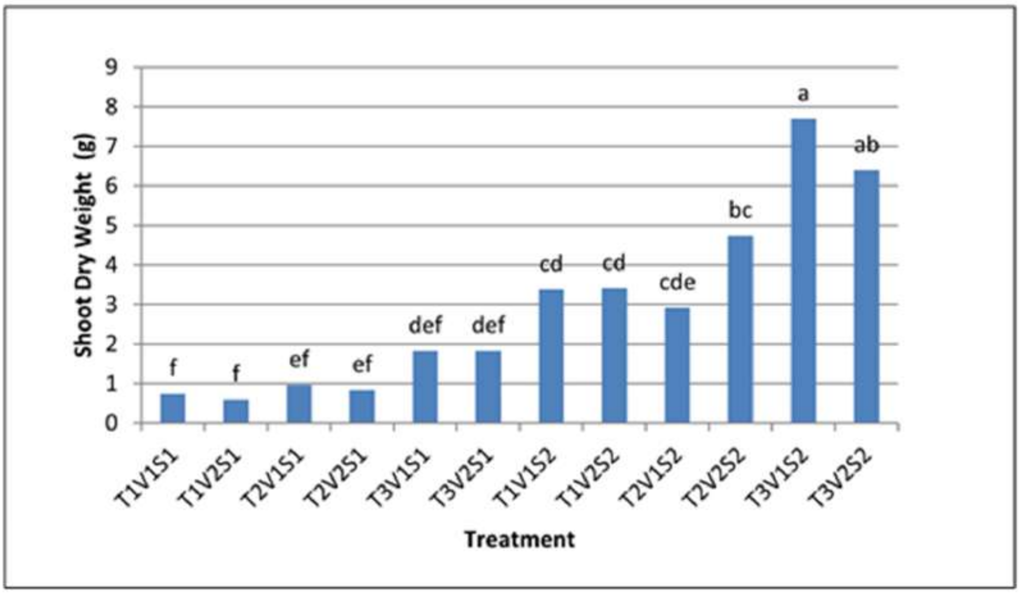

Figure 3. Effect of soil types, corn varieties, and soil sterilization on the leaf dry weight

being oven-dried. The data of the fresh weight of the corn plant leaves are presented in Figure 2.

Based on Figure 2, the treatment of unsterilized Alfisol and local corn variety (T3V1S2) resulted in the highest value of leaf fresh weight compared to other treatments. Meanwhile, the lowest value of leaf fresh weight was found in the treatment of sterilized Incepticol with local corn variety (T1V1S1). The highest leaf fresh weight was found in the unsterilized Alfisol treatment because the soil had the highest VAM infection rate compared to other soil types; this was related to environmental characteristics that supported the development of VAM such as pH and soil texture. In this treatment, no soil sterilization was carried out so that it did not eliminate VAM (Ortas et al., 2018).

Leaf Dry Weight

Plant dry weight is the weight of plant biomass after all the water content contained in the biomass is removed. Leaf dry weight is the net result of the photosynthesis process produced from the tip of the plant to the base of the plant stem (Samanhudi et al., 2018). This part is formed from the accumulation of carbohydrates and plant metabolism. The data of the leaf dry weight of corn plants are presented in Figure 3.

The local corn variety (T3V1S2) grown on the unsterilized Alfisol (Figure 3) resulted in the highest value of leaf dry weight compared to other treatments. Meanwhile, the lowest dry weight was found in the hybrid corn variety (T1V2S1) grown on sterilized Inceptisol.

Ortas et al. (2018) state that in general, plants grown on unsterilized soils grow better than those on sterile ones, which is due to the presence of VAM on the unsterilized soils that help provide nutrients. This is consistent with the results of their research showing that the presence of VAM significantly increased biomass uptake. Mawarni et al. (2013) state that VAM would infect plant roots so that the nutrient absorption process supporting photosynthesis would be used for preparing organic matters, thereby improving plant growth and dry weight. Whereas on sterilized soils, plant growth is reduced due to the elimination of VAM that have an essential role in plant growth (Ortas et al., 2016). Grant et al. (2005) state that the increase in plant biomass production by the presence of VAM can be triggered by plants requiring P since the beginning of their growth period.

Leaf P Content

The effects of the soil types, corn plant varieties and soil sterilization on the leaf P content are presented in Table 6 and Table 7.

Based on Table 6, there was an interaction effect of soil types and corn plant varieties on the leaf P content. The combination of Alfisol soil and hybrid variety showed the highest leaf P content

Table 6. Effects of soil types and corn plant varieties on the leaf P content

Soil types	Corn plant varieties		Mean
	Local variety	Hybrid variety	
Inceptisol	0.013 ab	0.013 ab	0.013
Mollisol	0.013 ab	0.005 b	0.009
Alfisol	0.013 ab	0.017 a	0.015
	0.013	0.012	(+)

Remarks: Values followed by the same letters in the same column are not significantly different according to Tukey's test (HSD) at 5 %.

Table 7. Effects of soil sterilization on the leaf P content.

Soil sterilization	Mean
S1	0.008 b
S2	0.017 a

Remarks: Values followed by the same letters in the same column are not significantly different according to Tukey's test (HSD) at 5 %.

compared to other treatments, namely 0.017. This result could be because, in the initial soil analysis, Alfisol had a lower available Ca content than other soil types but with the same available P content categorized in the low category, making Alfisol result in a higher leaf P content due to the lower content of Ca. Thus, the presence of Ca-P is not as high as in other soil types.

Based on Table 7, soil sterilization significantly affected the leaf P content. The highest leaf P content was in the treatment of soil without sterilization with a value of 0.017, while the lowest one was 0.008 in the sterilized soil treatment. The higher value of leaf P content in the treatment without soil sterilization is due to the presence of microorganisms, one of which is indigenous VAM. Vesicular-arbuscular mycorrhizae have fungal mycelium in the soil, which can absorb nutrients beyond the reach of effective absorption by widely reaching the soil (Syamsiyah et al., 2012). The effect of indigenous VAM colonization on P nutrients is often greater, which has an indirect effect on plant metabolism so that it has a symbiotic effect on other nutrients. Besides, the high content of P in plants with VAM is due to the ability of VAM to release phosphatase enzymes that can release AL-P, Fe-P, and Ca-P bonds (Bao et al., 2019).

Leaf P Uptake

Phosphorus is an essential nutrient, which is absorbed by plants in the form of monovalent phosphate anion ($H_2PO_4^-$) widely available at pH<7 and is absorbed more slowly in the form of divalent anion (HPO_4^{2-}) widely available at pH>7 (Sanjaya et al., 2013). Phosphorus plays an essential role in plant growth, such as photosynthesis, respiration, energy transfer and storage, and cell division and enlargement (Winarso, 2005). P is also essential for development of reproductive parts such as fruit and seed (Havlin et al., 2005). The values of leaf P uptake as affected by soil types, corn plant varieties, and soil sterilization are presented in Table 8 and 9.

There was an interaction effect of soil type and sterilization on the leaf P uptake (Table 8). Meanwhile, corn plant varieties did not significantly affect the leaf P uptake (Table 9). The treatment of un-sterilized Alfisol resulted in the highest leaf P uptake of 0.135 mg/plant compared to other treatments. Ortas et al. (2018) state that generally, plants grown on unsterilized soils showed a higher P content (%) than those grown in sterilized ones, and the presence of VAM was noted to produce a higher P content (%). Smith and Read (2010) state that the amount of P uptake through mycorrhizae (mycorrhizal pathways) could be higher than through host roots. Bao et al. (2019) stated that the mechanism of P distribution to plants was detected by the discovery of the transporter genes pf P OsPT11 and Gint PT (VAM pathway). Both were detected in all VAM infected plant samples

Table 8. Effects of soil types and soil sterilization on the leaf P uptake

Soil types	Soil sterilization				Mean (mg/plant)
	S1		S2		
Inceptisol	0.006	c	0.061	b	0.034
Mollisol	0.005	c	0.046	bc	0.025
Alfisol	0.019	bc	0.135	a	0.077
	0.010		0.081		(+)

Remarks: Values followed by the same letters in the same column are not significantly different according to Tukey's test (HSD) at 5 %.

Table 9. Effects of corn plant varieties on the leaf P uptake

Corn plant varieties	Mean	
Local variety	0.045	a
Hybrid variety	0.046	a

Remarks: Values followed by the same letters in the same column are not significantly different according to Tukey's test (HSD) at 5 %.

Table 10. The types of arbuscular mycorrhizae found in each corn variety based on the comparison of the fragment size with the sequence in the database

Treatments	Size (bp)	Types of Mycorrhizae	Acc. Number
T1V2S2	29	Acaulospora mellea	JN687473.1
		Gigaspora margarita	KX879062
		Septoglomus constrictum	MG253627.1
	49	Acaulspora sp	MT860453.1
	62	Acaulspora spinosa	JX461238
	79	Unidentified	-
	137	Acaulspora rugosa	LN881564.1
	198	Unidentified	-
	222	Unidintified	-
	285	Unidentified	-
T1V1S2	27	Gigaspora margarita	KY024214.1
		Acaulspora sp.	MT860453.1
	49	Acaulspora sp	MT860453.1
	64	Funnelisformis sp.	MT860454
		Gigaspora margarita	KC666029
	138	Gigaspora gigantean	AY919834
	197	Unidentified	-
	223	Unidentified	-
	279	Unidentified	-

but not in non-VAM roots.

Chen et al. (2014) reported that the main effect of VAM on plants was increasing the P uptake. Meanwhile, Astiko et al. (2019) state that the uptake of P and several other elements can be carried out by VAM from both soil and organic fertilizer residues even though the plants are not fertilized. George et al. (1995) mention that the length ratio of VAM hyphae to roots in the soil can be up to 100: 1 or greater, and with external hyphae, VAM roots can reach a wider area.

Leaf P uptake was not significantly affected by corn plant varieties. The leaf P uptake in local and hybrid varieties was 0.045 and 0.046 mg/plant, respectively. Khairiyah et al. (2017) stated that corn varieties did not have a significant difference in the growth when they were in the vegetative period. This could be caused by the effect of biofertilizers and the small number of microbial population density so that some of the functional characters of microbes in dissolving P from limited sources did not work optimally during the vegetative period.

Based on Table 10, the base pairs matched in the NCBI GenBank database, showing several VAM species in both treatments. Vesicular-arbuscular mycorrhizae identified in both treatments included *Acaulospora* sp., *Funelisformis* sp., *Gigaspora* sp., and *Septoglomus* sp. Ulfa (2011) mentions in his research that VAM have their own characteristics to adapt to changes that occur in the environment. It was stated that in the case of post-mining land, the genus of *Gigaspora* sp. and *Acaulospora* sp. are not very adaptive. Hadianur (2016) in his research also showed that the type of VAM fungi had a very significant effect on plant growth, especially *Gigaspora* sp., which can increase the growth of tomato plants, such as fresh root weight in vegetative phase, fresh root weight in vegetative phase, dry root weight in vegetative phase, dry root weight in vegetative phase and root length in vegetative phase and have a significant effect on nutrient uptake.

As this study showed that the presence of VAM could increase plant growth, such as increasing best results of root infection, leaf fresh and dry weight, leaf P content, and leaf P uptake, consequently, the use of VAM as a plant growth promoter can build sustainable agriculture. In addition, VAM can increase not only P but also other nutrients, thereby indicating the need to analyze different growth variables to evaluate plant response to VAM. It is also possible to further investigate the specific VAM species in each soil type and the role of species in the growth of plant species. This study showed a positive influence on plant growth.

CONCLUSION

The vesicular-arbuscular mycorrhizal detected in the roots of hybrid variety included *Acaulospora* sp., *Gigaspora* sp., and *Septoglomus* sp., and in the roots of local variety were *Acaulospora* sp., *Gigaspora* sp., and *Funelisformis* sp. The role of VAM can be seen through unsterilized soil so that there is no VAM elimination in the soil. The results showed that unsterilized soil showed the best results of root infection, leaf fresh and dry weight, leaf P content, and leaf P uptake. Soil type treatment showed that Alfisol showed the best result of root infection, fresh weight, dry weight, leaf P content, and leaf P uptake. The treatment of plant varieties showed that the varieties did not significantly affect the result of root infection, fresh weight, dry weight, leaf P content, and the best leaf P uptake.

ACKNOWLEDGMENT

Special thanks to Gadjah Mada University for the financial support to Fani Aulia Diannastiti through the final assignment review program (RTA), during her postgraduate program. The authors thank the comments and suggestions provided by reviewers.

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Variability of Agro-morphological Character and Genotype Clustering of Watermelon [*Citrullus lanatus* (Thunberg) Matsum & Nakai] as Basic Selection for New Variety

DOI: 10.18196/pt.v10i1.6936

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ABSTRACT

Watermelon [*Citrullus lanatus* (Thunb) Matsum & Nakai] is an important fruit commodity, which has the potential to be developed. Watermelon belongs to the cucurbitaceae family, which has advantages in terms of nutritional, environmental and economic values. Production of watermelon in Indonesia decreased from 2014 to 2016. Therefore, the productivity of watermelons could be increased by conducting this research. The aim of this research was to examine the variability of agro-morphological characters and clustering of watermelon. This research was conducted using seventy eight watermelon genotypes. Seventy-five watermelon genotypes and three commercial varieties were grown in an augmented design. Seventy-five genotypes were spread into four blocks, and each block contained the commercial varieties. The result of this research showed that the cumulative variability reached 81.22 %, with seventen main components and only five effective main components. Based on the cluster analysis, the seventy eight watermelon genotypes were divided into seven clusters, resulting in genetic distance of 0.486 - 0.999 and coefficient of similarity of 93 %. Ten watermelon genotypes selected based on consumer preferences can be used as recommendations to be released as a variety.

Keywords: Character, Clustering, Selection, Variability

ABSTRAK

Semangka [Citrullus lanatus (Thunb) Matsum & Nakai] merupakan komoditas buah penting sangat berpotensial untuk dikembangkan. Tanaman semangka yang tergolong dalam famili cucurbitaceae memiliki keunggulan dari segi nilai gizi, lingkungan maupun ekonomi. produksi semangka di Indonesia mengalami fluktuasi, namun dari 2014 ke 2016 produksi semangka di Indonesia pengalami penurunan. Upaya dalam mendukung perakitan varietas yang unggul untuk mendukung produktivitas semangka dengan mengadakan penelitian ini. Tujuan dari penelitian ini untuk mempelajari keragaman karakter agromorfologi dan pengelompokkan tujuh puluh delapan genotipe semangka. Tujuh puluh lima genotipe semangka uji dan tiga varietas komersial ditanam menggunakan rancangan acak kelompok yang diperluas (augmented design). Tujuh puluh lima genotipe tersebar dalam empat blok, setiap blok terdapat masing-masing tiga cek varietas. Hasil penelitian ini menunjukkan nilai keragaman kumulatif 81,22 % dengan tujuh belas komponen utama dan hanya lima komponen utama yang efektif. Pengelompokkan tujuh puluh delapan genotipe semangka berdasarkan karakter agromorfologi terbagi menjadi tujuh klaster menghasilkan jarak genetik berkisar 0,486 - 0,999 dan koefisien similarity 93 %. Sepuluh genotipe semangka yang memenuhi preferensi konsumen terseleksi dapat digunakan sebagai rekomendasi untuk dilepas sebagai varietas.

Kata kunci: *Karakter, Keragaman, Pengelompokkan, Seleksi*

INTRODUCTION

Watermelon [*Citrullus lanatus* (Thunb) Matsum & Nakai] is an important fruit commodity, which has the potential to be developed. Watermelon belongs to the cucurbitaceae family, which has advantages in terms of nutritional, environmental and economic values. Watermelon contains lycopene, which is useful for dealing with stress, cancer, cardiovascular and diabetes. Watermelon fruit also contains beta-carotene and Vitamin A (Naz et al., 2014). Rind of watermelon acts as a potential source of fiber, and it can reduce the glycemic index. The watermelon skin is usually processed into flour as a basic ingredient of cakes (Naknaen et al., 2016). The adaptation of watermelon can be categorized as good. Watermelons can grow in the lowlands to the highlands, from tropical to sub-

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Article History
Received: 28 Aug 2019
Accepted: 02 Feb 2021

tropical seasons. In sub-tropical areas, watermelons can grow to heights of 1,000 m above sea level and in tropical areas, watermelons can grow to 1,500 m above sea level (National Research Council, 2008). In South Africa, precisely in the desert and semi-desert areas, watermelon can grow wild (Vavilov, 1951). In terms of economics, watermelon is classified as the beloved fruit for table fruit.

Statistical data of FAO show that the development of watermelon production in Indonesia has fluctuated, but in 2014 to 2016, it decreased by 173,077 tons per ha (FAOSTAT, 2018). The decline in watermelon production may be influenced by environmental and genetic factors (Aragão et al., 2015; Dia et al., 2016). Differentiation of watermelon characteristics based on consumer and farmer preferences are expressed as agro-morphological characters. The visible characters in plants (color and shape) and all quantitative characters related to production that directly contribute to yield (seed size, number of seeds, and time of harvest) are included in agro-morphological characters (Jarvis et al., 2016). The variability of agro-morphological characters and genetic distances are used for the selection of potential genotype to be developed as a variety. The characters of watermelon used as a reference for selection include the visualization of the color of the fruit flesh and the weight of the fruit (Bang et al., 2010; Ilahy et al., 2019).

The information of watermelon genotypes that will be obtained through this research can be used as materials for breeders to develop varieties. Watermelon genotypes obtained from the line or variety being developed are from the Asian, African and European Continents. It is possible that there are variations in the diversity of agro-morphological characters between genotypes of watermelons, in which the more variety and genetic distance between genotypes, the more options available to breeders to assemble varieties. Information on the characteristics of plant traits and methods of breeding in an effort to improve plant traits can be seen through genetic parameters, such as variability of character, heritability and genetic progress (Assefa et al., 2020; Mahla & Choundhary, 2013).

MATERIALS AND METHODS

Experimental Design

This research was conducted in January - May 2019 in Seed Bank and Nursery, AgroTechno Park, Academic Business Entity, Brawijaya University, Jatikerto Village, Kromengan District, Malang Regency. Planting materials used in the study were 28 family, consisting of 75 genotypes. Three commercial varieties (Biggie F1, Sunflower F1 and Amor F1) as check genotypes (Table. 1). The watermelon families are the results of the selection of pure lines from various countries by the Laboratory of Plant Breeding, Faculty of Agriculture, Brawijaya University, Malang. Line of [BW] is from Indonesia, [TH] is from Thailand, [VN] is from Vietnam, [TR] is from Turkey, and [LB] is from Libya. Meanwhile, Crimson Sweet is from commercial varieties produced in the United States.

This research was conducted based on an experimental method compiled with an extended randomized group design or augmented design. The seventy five watermelon genotypes were spread in 4 blocks, and each block planted with 3 commercial varieties as check genotypes. The limited number of seeds per genotype and the large number of genotypes are the reasons for using this augmented design (Mramba et al., 2018). Compared to the randomized complete block design, which requires replication of the genotypes tested in each block, in an extended randomized group design or augmented design, replication was only made to the check genotypes (commercial varieties) (Frank et al., 2016). Variability can be controlled, and genotypes efficiently can be assessed through

Table 1. Genotypes used in the study

No.	Family	Genotypes
1.	Clan[BW]-01	Clan[BW]-01#1
2.	Clan[BW]-02	Clan[BW]-02#1 and Clan[BW]-02#3
3.	Clan[BW]-03	Clan[BW]-03#1
4.	Clan[BW]-04	Clan[BW]-04#1, Clan[BW]-04#2, Clan[BW]-04#3 and Clan[BW]-04#4
5.	Clan[BW]-05	Clan[BW]-05#1, Clan[BW]-05#3 and Clan[BW]-05#4
6.	Clan[BW]-06	Clan[BW]-06#1, Clan[BW]-06#2, Clan[BW]-06#3 and Clan[BW]-06#4
7.	Clan[BW]-07	Clan[BW]-07#1, Clan[BW]-07#2, Clan[BW]-07#3 and Clan[BW]-07#4
8.	Clan[BW]-08	Clan[BW]-08#1, Clan[BW]-08#2, Clan[BW]-08#3 and Clan[BW]-08#4
9.	Clan[BW]-09	Clan[BW]-09#2
10.	Clan[BW]-10	Clan[BW]-10#1, Clan[BW]-10#2, Clan[BW]-10#3 and Clan[BW]-10#4
11.	Clan[BW]-11	Clan[BW]-11#1
12.	Clan[TH]-01	Clan[TH]-01#1, Clan[TH]-01#3 and Clan[TH]-01#4
13.	Clan[TH]-02	Clan[TH]-02#1, Clan[TH]-02#2, Clan[TH]-02#3 and Clan[TH]-02#4
14.	Clan[TH]-03	Clan[TH]-03#2 and Clan[TH]-03#3
15.	Clan[TH]-04	Clan[TH]-04#1, Clan[TH]-04#2 and Clan[TH]-04#3
16.	Clan[TH]-05	Clan[TH]-05#1 and Clan[TH]-05#4
17.	Clan[TH]-06	Clan[TH]-06#1, Clan[TH]-06#2, Clan[TH]-06#3 and Clan[TH]-06#4
18.	Clan[TH]-07	Clan[TH]-07#1, Clan[TH]-07#3 and Clan[TH]-07#4
19.	Clan[TH]-08	Clan[TH]-08#1, Clan[TH]-08#2 and Clan[TH]-08#3
20.	Clan[TH]-09	Clan[TH]-09#1 and Clan[TH]-09#2
21.	Clan[TH]-10	Clan[TH]-10#1, Clan[TH]-10#2 and Clan[TH]-10#3
22.	Clan[LB]-02	Clan[LB]-02#2 and Clan[LB]-02#4
23.	Clan[LB]-03	Clan[LB]-03#2, Clan[LB]-03#3 and Clan[LB]-03#4
24.	Clan[TR]-01	Clan[TR]-01#1 and Clan[TR]-01#2
25.	Crimson Sweet	Variety
26.	Clan[VN]-01	Clan[VN]-01#1 and Clan[VN]-01#2
27.	Clan[VN]-02	Clan[VN]-02#1, Clan[VN]-02#2, Clan[VN]-02#3 and Clan[VN]-02#4
28.	Clan[UB]-01	Clan[UB]-01#2, Clan[UB]-01#3 and Clan[UB]-01#4
29.	Biggie F1	Variety Commercial
30.	SunflowervF1	Variety Commercial
31.	Amor F1	Variety Commercial

augmented design. New genotypes and varieties are compared in this design. Variety (c) that functions as a replicated check (r) in each trial block and a new genotype (n) were tested one replication in each block (Federer & Crossa, 2012). Observations were made on 65 agro-morphological characters, consisting of stem, leaf, flower, and fruit characters. Qualitative observations were made using the scoring method, and quantitative data were taken on average.

Statistical Analysis

The collected data were analyzed using the XLSTAT version 2014.5.03. Meanwhile, the variability of agro-morphological characters was analyzed using Principal Component Analysis (PCA). Percentage of variation to total variability is explained through each component, and a large set of data can be reduced to smaller components that have strong inter-correlations in the set of variables sought (Das et al., 2017). Variations that can be measured using PCA divide total variance into new components. That loading factor and eigenvalue value will determine the variance of a plant character is the reason why PCA analysis is used (Pour-Aboughadareh et al., 2017). Eigenvalue >1 determines the main components that affect total variability, and the loading factor > 0.6 (Guadagnoli & Velicer, 1988) is used to determine the contributing characters. Meanwhile, the genetic distance was estimated using Agglomerative Hierarchical Clustering (AHC) with UPGMA procedure based on similarity values. This analysis of individuals is grouped according to their similarity (Mohammadi & Prasanna, 2003).

RESULTS AND DISCUSSION

Variability of Agro-morphological Characters in Watermelon Genotypes using Principal Component Analysis

Based on the results of PCA analysis with an eigenvalue > 1, seventeen main components of the agro-morphological characters were obtained. The 17 main components of the agromorphological characters produce a cumulative variability value of 81.22 % (Table 2). Of the seventeen main components, there were only 5 effective (main components) PCs. The value of cumulative variability and eigenvalue decreases with the increasing value of the main component. This also relates to the number of characters that contribute to a component. The first main component (PC1) with a eigenvalue of 9.42 was dominated by the length of the stem, number of leaves, number of male flowers, diameter of the fruit stalks, size of insertion of peduncle, fruit diameter, pericarp thickness, degree of leaf lobing, leaf blistering and strip width. The characters of leaf length, leaf width, fruit length, and seed weight per fruit are the characters that contribute to the variability of PC2, which has an eigenvalue value of 6.17. In PC3 with the eigenvalue value of 4.64, the contributing characters were the longitudinal shape of the fruit and the main color of the stripe, while in PC4, the contributing character was the segment of the first female flower. Eigenvalue of 3.85 places the seed width character as the dominant character in PC5. The cumulative value of 83 % of the contributing characters are fruit weight, % TSS, flowering period, rasio of fruit length and diameter, and ratio of the number of female flowers and male flowers (Sheng et al., 2012). The number of branches, fruit weight, fruit length, main stem length, fruit skin thickness, % TSS, and fruit width give a cumulative value of 82.14 % (Said & Fatiha, 2015). Such results can be seen that each character that produces a variability cumulative value varies. The characters that show varibility depend on the observed genotype population. Most of the characters that showed varibility are fruit weight, fruit length, fruit skin thickness, number of branches, stem length, and % TSS. Compared with the results of this study, the length of the stem and the thickness of the skin required the most varied characters.

Table 2. Characteristics of potential genotypes for variety release

Genotype	Characters							
	Day of harvesting (dap)	Weight of fruit (kg)	Thickness of pericarp (mm)	^{0}Brix	Shape of fruit	Main color of flesh fruit	Main ground color of skin fruit	Cluster
Clan[BW]-07#3	64	1.42	11.25	10.65	medium elliptic	red	Dark green	1
Clan[BW]-07#4	75	0.41	4.25	9.00	medium elliptic	red	Dark green	1
Clan[TH]-09#2	67	1.61	8.20	10.00	circular	red	Dark green to very dark green	2
Clan[TH]-05#4	84	0.89	9.30	10.00	circular	red	Dark green	1
Clan[TH]-07#1	78	1.47	8.65	8.90	medium elliptic	red	Medium green to dark green	
Clan[TH]-08#2	84	0.89	7.25	9.10	circular	red	Medium green to dark green	1
Clan[TH]-10#1,	100	0.88	7.00	9.60	medium elliptic	dark red	Dark green	1
Clan[VN]-02#1	88	1.65	7.40	8.40	broad elliptic	yellow	Dark green to very dark green	6
Clan[UB]-01#4	78	0.88	9.72	8.90	medium elliptic	yellow	Dark green to very dark green	2
Clan[VN]-02#4	95	0.75	9.90	7.20	broad elliptic	orange	Medium green	2

Genetic Distance of Watermelon Genotypes based on Agro-morphological Characters

Seven clusters of watermelon genotypes were produced with a genetic distance of 0.486-0.999 and a similarity coefficient of 93% (Figure 1). Clusters start from the smallest to the largest number of genotypes. Cluster 4 and cluster 7 fonsist of 1 genotype, while clusters 5 and 6 consist of two genotypes. Meanwhile, cluster 1 consisted 24 genotypes. The position of the largest cluster is in cluster 2 with 43 genotypes . Amor and Biggie, as check genotypes (commercial varieties), have the closest genetic distance, while Clan[LB]-03#3 with Clan[VN]-02#3 are genotypes that have the furthest genetic distance. The genotypes from Indonesia, Thailand, Vietnam, Libya and Turkey are spread in each cluster. This means that each cluster is not grouped based on genotypes from the same country. In other words, genotypes from the same family/breed are located in different clusters. This indicates that there are still variations in the characters of a family/line. Similar results occur in previous grouping studies of watermelon genotypes. The clustering was not based on geographical distribution, although the accessions observed were from 7 different countries (Ahou et al., 2016). These variations of character can occur because this study using the phenotypic method (agromorphological characters), resulting in character variations even though they are from the same family/breed. The solution of this case is the need for a molecular methodology to validate the results of phenotypic measurements since the use of molecular methodology is very common in genetic diversity research. Molecular methodology with markers (isozymes, RFLP, AFLP, RAPD, SSR, SRAP, CAPS) is used to detect the genetic variations. SRAP molecular markers are efficient in watermelons that have low genetic diversity (Uluturk et al., 2011).

Watermelon Genotype Selection based on Fruit Characteristics

The characters used as a basis for the selection of genotype include the characteristics that can succeed a variety characterized by attractive fruit features. High yield, shape, weight, skin, flesh, and seeds are considered attractive fruit characteristics. The character component is important, considering that fruits with certain characters will be marketed according to different categories. The appearance of cut fruit is more attarctive if it has a seed color that contrasts with the color of the fruit flesh. Consumers usually swallows the small seeds, while the large seeds will be separated when consumed. Thus, fruits that have small or medium seeds are more commonly found in commercial varieties than fruits with large seeds (Gusmini & Wehner, 2006). Commercial watermelons in America are divided into several categories. Watermelons that are included in the category of mini-sized fruits have a weight of < 4 kg. Mini watermelon has a great chance to be accepted in the market, because mini watermelon is very practical for consumption to individual consumer. The size of watermelons ranging from 2-3 kg is currently being developed, targettng families of 1-2 members, especially for young children. The last selection category is based on the color of the stripe pattern on the watermelon skin. The preferred color of stripe pattern on watermelon skin is wide striped pattern with a dark green color (Maynard & Paris, 2006).

Based on the statement above, it can be seen that consumers want mini-sized fruit characters (< 4 kg) with perfect fruit flesh color, stripes on green fruit skin, high sugar content (Brix^{o}), and circular or elliptic shape. Fruit that is characterized as whole, dense, fresh appearance, suitable for consumption,and reaching a sufficient level of maturity (minimum 8^{o}Brix) is a minimum re-

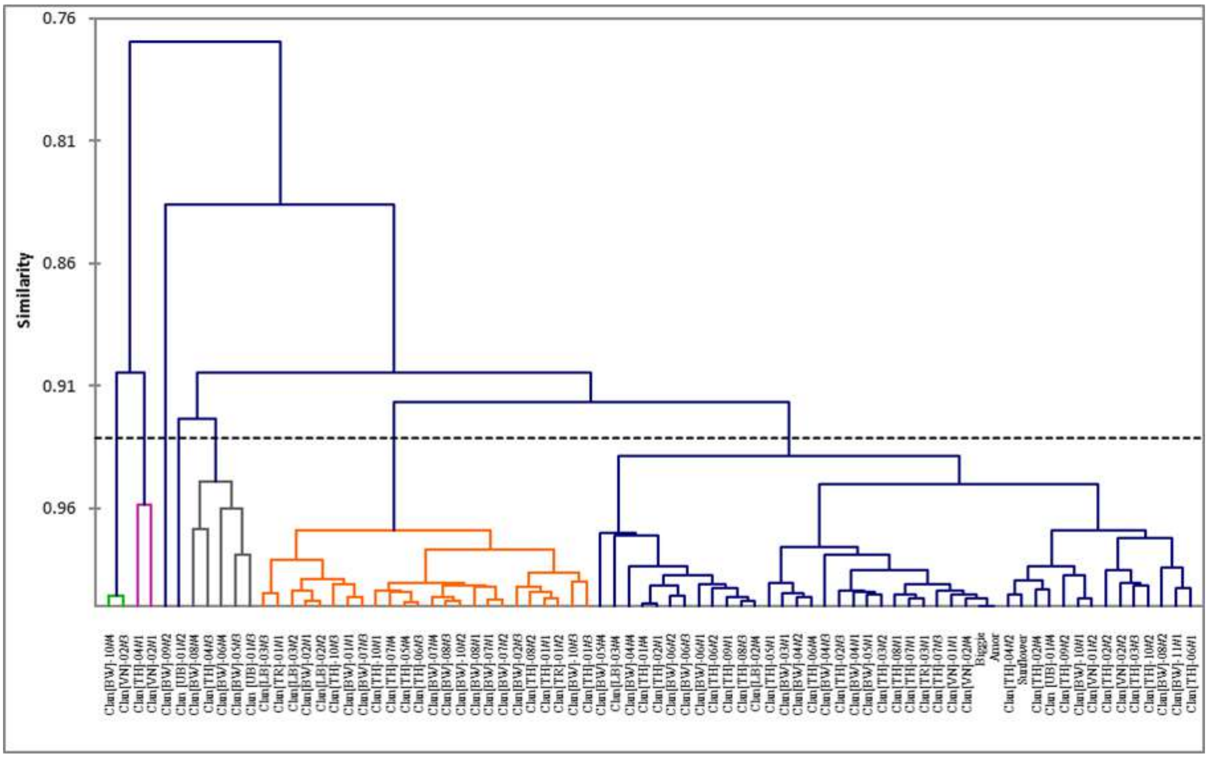

Figure 1. Grouping of seventy-eight watermelons divided into seven clusters based on sixty-five agro-morphological characters

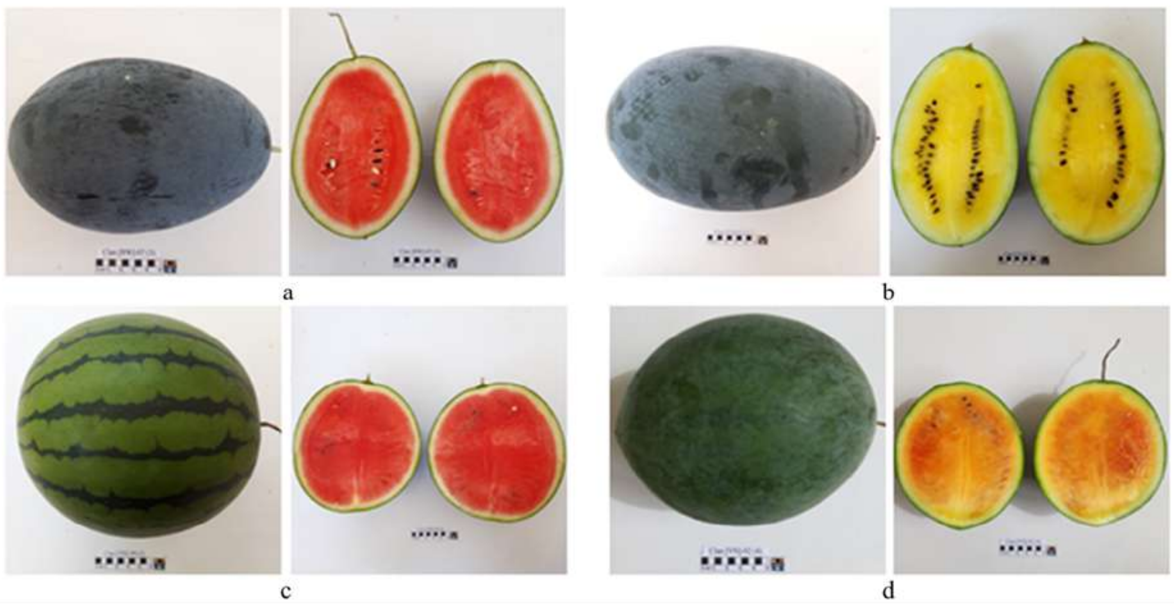

Figure 2. The appearance in fruit characters of watermelon genotypes potential for varieties to be released. Note: a) Clan[TH]-07#1; b) Clan[VN]-02#1, c) Clan[TH]-09#2, d) Clan[VN]-02# 4

quirement of the Indonesian National Standard (Badan Standardisasi Nasional, 2009). Watermelon genotypes requiring selection criteria based on consumer preferences are shown in Table 3, and some genotypes showing the appearance of fruit characters are presented in Figure 2. The genotypes include Clan[BW]-07#3, Clan[BW]-07#4, Clan[TH]-09#2, Clan[TH]-05#4, Clan[TH]-07#1, Clan[TH]-08#2, Clan[TH]-10#1, Clan[VN]-02#1, Clan[UB]-01#4, and Clan[VN]-02#4. The ten selected genotypes varied. Variation of each genotype has a great chance to be released as a variety, which is distributed in clusters 1, 2, and 6. One of the techniques in multivariate analysis is used to select criteria in selecting elders, namely by measuring genetic distances based on phenotypic characters (Bertan et al., 2005).

CONCLUSION

The variability of watermelon agro-morphological characters was 81.22% with 5 effective PCs. Variation of characters varied in stem length, number of leaves, number of male flowers, stem diameter, sticking of fruit handle, fruit diameter, pericarp thickness, degree of leaf curvature, leaf blistering, stripe width, leaf length, leaf width, leaf length, fruit length, seed weight per fruit, longitudinal shape of the fruit, the main color of the strip, the emergence of female flower, and the width of the seeds. The genetic distance of watermelon ranged from 0.486 to 0.999 in 7 clusters. Ten watermelon genotypes that meet consumer preferences are used as variety recommendations.

ACKNOWLEDGEMENTS

The authors would like to thank the funders of research and facilities of Seed and Nursery Industry, Agro Techno Park, Universitas Brawijaya Academic Business Entity.

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Agrobiodiversity as Necessary Standard for the Design and Management of Sustainable Farming Systems

DOI: 10.18196/pt.v10i1.14105

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ABSTRACT

Agriculture constitutes the major planetary force, which over the course of the past century has been changing forever the connotations of terrestrial ecosystems, due to its dependence on resources and impacts (e.g.: global climate change, biodiversity loss, pollution, and eutrophication of fresh and coastal waters). The purpose of this work aimed at demonstrating the compelling need to design and manage modern farms in a way that these may conserve, and even foster biodiversity because its restoration offers resilience, longevity, and productivity to 21st century farms. Therefore, special emphasis in this work was given to the management of agricultural soils and agroforestry. These approaches enhance biological diversity, while strengthening the health of plants, animals, and human communities thus, contributing to the health of planet Earth. Agroecology is the science, practice and social movement that effectively, can assist with a conversion of farming systems toward sustainability and a restoration of agrobiodiversity.

Keywords: Climate change, Biodiversity loss, Pollution, Sustainability

ABSTRAK

Pertanian merupakan kekuatan utama planet, yang selama beberapa abad telah mengubah makna ekosistem terrestrial, karena pertanian memiliki ketergantungan pada sumber daya dan menimbulkan dampak pada sumberdaya itu sendiri (misalnya: perubahan iklim global, hilangnya keanekaragaman hayati, polusi, dan eutrofikasi air tawar dan pesisir). Tujuan dari studi ini ditujukan untuk menunjukkan kebutuhan yang penting untuk merancang dan mengelola pertanian modern dengan cara yang dapat melestarikan dan mendorong keanekaragaman hayati, karena cara tersebut menawarkan ketahanan, keberlanjutan pertanian jangka panjang, dan produktivitas untuk pertanian abad ke-21. Sehingga, penekanan khusus pada studi ini diberikan pada pengelolaan tanah pertanian dan agroforestri. Pendekatan ini akan meningkatkan keanekaragaman hayatinya yang dapat memperkuat kesehatan tanaman, hewan, dan komunitas manusia sehingga berkontribusi pada kesehatan Bumi. Agroekologi adalah ilmu, praktik dan gerakan sosial yang secara efektif dapat membantu konversi sistem pertanian menuju keberlanjutan dan pemulihan agrobiodiversitas.

Kata kunci: Perubahan iklim, Keanekaragaman hayati, Polusi, Keberlanjutan

INTRODUCTION

For the last 10.000 years, agriculture has been playing a pivotal role in securing humans' food needs and for contributing to people's health and well-being. The latter is substantiated by a successful establishment of civilizations in various regions of the world where agriculture first occurred. An exponential growth of the human population during the last 200 years of human history could be considered another remarkable success of agriculture, that was amplified by the technological breakthroughs of the industrial revolution, like the combustion engine and more implements, that were successful in boosting crop yields. Nevertheless, since the onset of agriculture an on-going conversion of land to farmland has been occurring at an increasing scale, through millennia (Mazoyer M & Roudart L, 2006). At present, scientists have calculated that livestock and crops agriculture have been shifting the 39% of all suitable lands to food production (Foley et al., 2011), making agriculture and the technologies it uses such as: transgenic crops, agrichemicals, computer networks, automa-

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Article History
Received: 24 Dec 2021
Accepted: 03 Feb 2022

tion, and large farm implements, a geologic force whose scale of disruption has forever changed the attributes of terrestrial biomes (Rockström J & Gaffney O, 2021).

The relevance of this work is about the urgent need of changing agriculture into a more sustainable paradigm of regenerative and restorative food production, making agroecology a suitable vehicle for transformation and for achieving sustainability in modern farming. An agroecological approach to agriculture appears to be applicable to all farms and beneficial to people and the environment. Thus, the focus of this paper was directed to:

- Demonstrate how a design and management of modern farms with agroecology can preserve and even augment biodiversity.
- Illustrate the interconnectedness between soil biodiversity and agrobiodiversity.
- Present agroecology as the science, practice and social movement that can assist with a conversion of farming systems toward sustainability.

Agriculture relies heavily on the abundance and diversity of species that are cultivated, including those already existing on site, and that can be measured on a farm (Duru et al., 2015; Nicholls CI & Altieri MA, 2016). Biodiversity can be considered at various levels spanning from the genetic diversity within a population to the community level, where it expands to describe diversity among multiple populations (Primack RB, 2006). Every species has its specific function in every ecosystem, despite inevitable redundancy, which is necessary to support ecological resilience thus, making biodiversity a keystone service whose losses indicate clear signals that humanity's life support system is out of balance (Tallamy DW, 2009). Since the beginning of agriculture in Neolithic times, the biomass from terrestrial plant species has been reduced 50% of its estimated diversity (Erb et al., 2018). According to Díaz and team (2019), this loss equals a loss of more than 20% of the original biodiversity among plants, implying that 70% of the Earth's land surface, which includes also large, marginal areas not as suitable for agriculture, has been severely disturbed by human activities (IPBES & Willemen, 2018). Primary causes of biodiversity loss are reported (Table 1).

Therefore, there is an urgent need to remediate from the loss of biodiversity to avert grave consequences that may jeopardize quality of life as we know it and to prevent a collapse of food systems, and associated food supply chains. A roadmap to transform agriculture and veer food production toward sustainability has been proposed, with specific emphases that aim at:

- Enhancing the regenerative capabilities of farming where land managed in agricultural systems is converted to sequester carbon, instead of continuing to emit carbon (Rockström J & Gaffney O, 2021; Borsari B, 2022).
- Reducing, or even better eliminating food spoilage and waste (IPBES & Willemen, 2018).
- Embracing unilaterally the planetary diet as proposed by the EAT-Lancet Commission (Rockström J & Gaffney O, 2021).
- Stabilizing the human population to a size that is compatible with the regenerative capabilities of Earth, to avoid exhausting resources and without reaching the population carrying capacity.

However, it remains uncertain whether agriculture around the world will follow these guidelines, or not. The mentioned urgency consists in avoiding further greenhouse gas emissions (GHGs) in the atmosphere that could worsen the climate change

Table 1. Causes of Biodiversity Loss and its Consequences.

Biodiversity Loss	Effects/Outcomes
Habitat destruction	Agriculture* and Infrastructure (railroads, airports, urbanization, industry, etc.)
Global Climate Change	Habitat and food loss from temperature change. Disruption of migration patterns
Pollution of air, land, and water	Fossil fuels, pesticides, sewage, solid waste.
Non-native species	Cats and rats on islands, water hyacinth and more.
Overexploitation	Species hunted for food, pet trade, medicine. Logging, mining, fishing, groundwater extraction.

*Agriculture is the keystone cause of habitat and biodiversity loss, climate change and pollution.

scenarios to the point beyond recovery and control. There is a need of mobilizing society across geographic boundaries, economies, and culture, in a unilateral effort to comply and achieve the 17 goals for sustainable development (SDGs) of agenda 2030, as proposed by the United Nations, six years ago.

THE BENEFITS OF AGROBIODIVERSITY IN AGROECOSYSTEMS

Agrobiodiversity provides a multitude of valuable benefits to farming systems, while extending the same to the surrounding landscape where food production is taking place (Duru et al., 2015; Nicholls CI & Altieri MA, 2016; Borsari B, 2022). More specifically, high biodiversity on the farm means:

- Greater microhabitat differentiation (Zucconi F, 1996).
- Increased opportunities for coexistence among beneficial species (Borsari B, 2022).
- Making possible various kinds of beneficial population dynamics among herbivores and their predators (Nicholls CI & Altieri MA, 2016; Lampkin N, 1999).
- Better resource use in the agroecosystem (e.g.: three sisters intercropping and their use of soil nutrients) (Gliessman S, 2015).
- Reducing risks of crop failure for the farmer (Borsari B, 2022).
- Contributing to the conservation of diversity in nearby natural areas (Nicholls CI & Altieri MA, 2016; Borsari et al., 2016).

Moreover, diversity of the soil food web benefits nutrients recycling, regulation of local hydrological processes and detoxification of noxious chemicals, making these processes and services renew soil fertility and health. These advantages have been forgotten due to an excessive reliance of agriculture on input substitution from off farms, that for the last seventy years have been praised as the necessary means and technologies needed to achieve success in food production (Gliessman S, 2015). However, this western approach has marginalize indigenous knowledge and wisdom of farming, while spurring a significant loss of landrace seeds that were deemed irrelevant, or unprofitable by emerging agribusiness corporations (Borsari B, 2022). A restoration of indigenous knowledge in agriculture is much needed instead to conserve native germplasm for future generations and to assist also with a diversification of the human diet.

Agronomic Approaches to Foster Agrobiodiversity in the Soil

The most intuitive example for increasing agrobiodiversity consists in intercropping more than one plant or grazing more than one animal species in the same field. More strategies could include:

- Cover cropping
- Crop Rotations
- Intercropping (Mexican milpa as classic example with three sisters' cultivation method)
- Fallow cropping (resting field)
- Reduced, or minimum tillage

- High organic matter (OM) inputs (compost)
- Reducing/eliminating the use of agrichemicals
- Employing trees (Agroforestry)

The challenge consists in designing agroecosystems that rely on resources already available on the farm and that blend in with the surrounding, natural landscape, while being aware of the ecological benefits that derive from it and thus, remaining committed to conserve and maintain its integrity (Nicholls CI & Altieri MA, 2016; Gliessman S, 2015; Lampkin N, 1999).

AGROBIODIVERSITY AND AGROFORESTRY CONTRIBUTE TO SOIL HEALTH

The abundance of life within the soil and the diversity of the soil community plays a very important role in achieving a healthy soil, which will enhance the health of all crops and livestock that depend on it (Borsari et al., 2016). The processes occurring in a soil that is biologically rich, contribute most effectively to an enhancement of carbon sequestration and humification, as it occurs during the composting process (Nair PKR, 2002).

Therefore, various types of biomass and crop residues (e.g.: foliage, stubble, chaff, brush) and/or animals' manure that left, or disked into the topsoil, will be transformed in humus (stable organic matter), are excellent resources for enhancing soil quality (Nair PKR, 2002). Consequently, when conducting an evaluation of soils, indicators like microbial activity and the amount of stable organic matter (OM), derived from biomass humification will be keystone markers of soil quality and health. Humus is a very stable form of carbon and thus, it is a pivotal component of soil fertility (Borsari B, 2020), making an understanding of the carbon cycle occurring within the soil and the biological processing of raw organic matter important knowledge that when applied to agriculture, assists farmers to restore soil fertility (Zucconi F, 1996). The fresh/raw OM goes through two distinctive humification process trajectories that can be fast, or slow depending on biotic factors (e.g.: richness and diversity of soil biota), and abiotic conditions such as: aerobiosis, air temperature, humidity, and carbon/nitrogen ratio of the biomass to be processed. Initially, both decomposition paths will yield organic compounds that are chemically unstable and toxic, removing water and carbon dioxide from the biomass, through exothermic reactions (Figure 1).

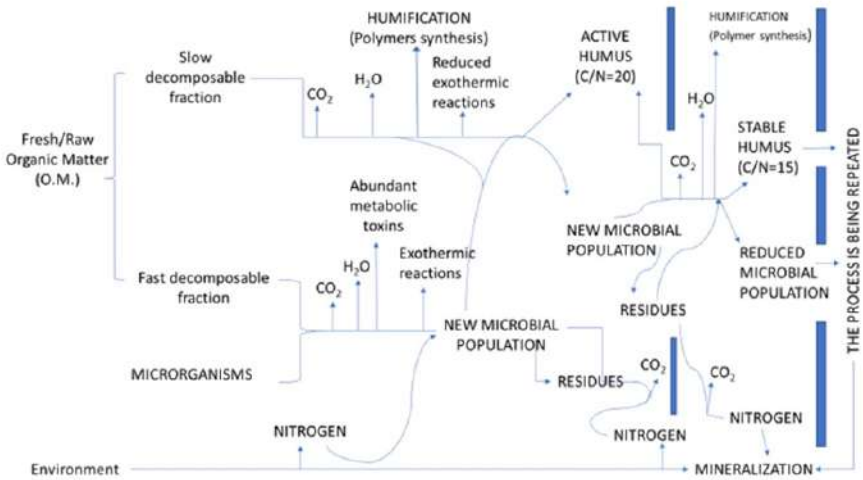

Figure 1. Cycle of decomposition and humification of fresh/raw organic matter (Borsari, 2020)

At this stage of the process is not advisable to apply OM that is only partially humified, to seedlings, or germinating seeds, without incurring in toxicity induced damages to these. Only at the end of humification, when the mass will be reduced significantly in volume, the same becomes dark in color and earthy smelling, indicating the presence of actinomycetes. Its carbon/nitrogen ratio will drop to a more balanced ratio (C/N ~ 15). At this stage, the humus rich compost will be chemically stable and ready to be used (Lampkin N, 1999). Also, the molecules yielded prior to the mineralization stage of the humification process (where mineralization refers to the decomposition/oxidation of macromolecules present in the OM, by which the nutrients in those compounds are released in soluble inorganic forms and become available to plants for uptake by their roots), stabilize the carbon molecules that have been converted in humus, which will accumulate in the topsoil (Nair PKR, 2002). This will make the soil retain moisture and plant nutrients, improving its resilience from disturbances like tillage, while enhancing its overall health.

Thus, a quantitative evaluation of soil health should include a variety of field measurements, in addition to standard soil nutrient analyses. These methodologies are available to farmers, enabling them to make the best decisions for planning and implementing practices of soil health enhancement and management that reduce the impacts of agricultural stressors (Moebius-Clune et al., 2017). However, it remains still difficult to find an agreement about adopting standardized methods when evaluating soil quality and health, despite the array of indicators available (Laishram et al., 2012). If the focus of a soil health assessment is adaptive to climate change, then key indicators should comprise soil structure, OM, available carbon and nitrogen, microbial activity, including abundance and diversity of soil biota (Borsari et al., 2016; Nair PKR, 2002; Allen et al., 2011). Present knowledge

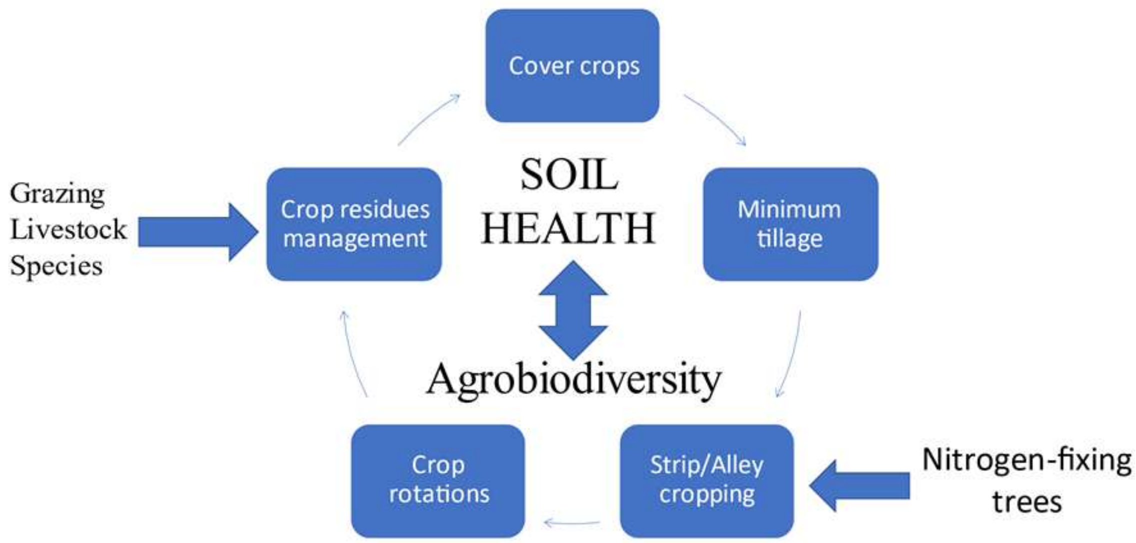

Figure 2. The nexus between soil health and agrobiodiversity relies on agronomic practices that prioritize an ecological management of the soil ecosystem (Borsari, 2022)

about soil quality has improved in recent years, to clarify how soil health can be enhanced, or reestablished when it is affected by conventional farming practices. Yet, some barriers are still affecting a valid quantification of soil health by the fact that this topic is still new and by measurements that continue to be taken only in the topsoil (horizon A of the soil profile), ignoring deeper horizons (Sparling et al., 2004). Nonetheless, an integration of agronomic techniques, which includes also grazing animal species and nitrogen fixing trees will eventually, strengthen agrobiodiversity and soil health when these practices will become established permanently, in farm management (Figure 2).

Agroforestry in Agroecosystems

Agroforestry is an intentional integration of trees, crops and/or livestock in agroecosystems, where interactions are managed intensively. An employment of trees and other woody plants like shrubs can be a feasible approach to enhance agrobiodiversity and resilience in farms, while boosting a variety of additional products and services, that can increase the profitability of the farm enterprise (Gliessman S, 2015). Whether agroforestry is complemented by livestock grazing (e.g.: silvopasture), or the cultivation of agronomic plant species like in alley cropping, trees and other perennial plants are valuable to protect the farm and its crops, from soil erosion through windbreaks, or riparian buffer zones. Moreover, forest plots can be considered agroforestry systems when these are farmed with economic crops like mushrooms, medicinal plants, or woody plant species that can be used for construction and/or as a renewable energy source, for cooking and heating purposes.

Although agroforestry systems are ubiquitous their prevalence is in the agrarian landscapes of tropical and sub-tropical regions of the world. Their design and size may change according to topography, climate, soil characteristics, hydrology, and economic purpose from which market demand for its products and services depend. For example, in sub-tropical highland regions of India, with altitudes > 1000 m above sea level, agroforestry has become a key approach to farming, and for protecting soil from erosion. Therefore, intercropping bamboo (*Bambusa spp.*) and rice (*Oryza sativa* L.), with an integration of aquaculture constitutes the design and practice of common agroforestry systems in these dry regions, where scarce rain precipitations and high daily temperatures, cause frequent droughts (Raj et al., 2021). More specifically, agroforestry has been beneficial to farmers in the dry corridor of Rajasthan, to diversify farm products through an inclusion of Ghaf trees (*Prosopis cineraria*), together with cereals and pulses, thus, enhancing economic gains and agrobiodiversity (Dhanya et al., 2014). An integration of pigs who are raised often in bamboo shelters built on the edge of the rice fields, adds meat to the number of products (e.g.: fish, rice, bamboo) and services (e.g.: pig manure as feed for the fish and animal waste), including scales, and nitrogen-rich manure, that restores soil fertility in countries of southeast Asia. These multifunctional agroecosystems provide food security for local communities, while maintaining an optimal level of land use for agriculture (Tangjang S, 2016). In the dry arc (Arco seco) region of Panama instead, the Physic nut tree (*Jatropha curcas* L.) is employed in silvopasture, as a viable species to construct live fences for containing cattle and for producing biodiesel from the seed harvested from this tree (Espinosa–Tasón et al., 2016).

Also, home gardening can be considered common and productive agroforestry systems that are cultivated in many tropical and non-tropical regions of the world, including urban and peri-urban areas (Orsini et al., 2020). These and similar growing spaces have potential to improve farmers' income while securing food for their families and communities. Fruit and nut trees bear these products in the upper layer of their canopy, intermingled with vines (e.g.: spice crops) growing in the middle layer, whereas the understory is designed to grow cash crops, or medicinal plants, even on small spaces. Green hedges employing an assortment of trees and shrubs mark the boundaries among adjacent home gardens, making this form of intentional landscape, an ancient landscaping practice (Raj et al., 2021). Agroforestry gardens replenish the built environment with abundant edible products enhancing air quality, water retention and more ecological services, while beautifying the urbanscape. Also, green, live hedges function as fences/windbreaks, improving soil fertility by adding some of their biomass to the soil nearby (Gliessman S, 2015). Instead, an integration of trees with grasses, pulses, and grazing livestock, or silvopasture, consists in a distinctive form of agroforestry where a well-maintained plant community is supportive of the nutrition and health of the animals. Iconic tree species used in tropical and sub-tropical silvopasture include neem (*Azadirachta indica*), mango (*Mangifera indica*), acacia (*Acacia nilotica*), or Leucaena (*Leucaena leucocephala* Lam.), whereas in temperate regions oaks may be common (*Oak spp*.), including the cork oak (*Quercus suber*) of the "dehesa" in Spain, or black locust (*Robinia pseudoacacia*), willow (*Salix spp*.), poplar (*Populus spp*.). Silvopasture supplies distinctive ecosystem services that maintain the ecological balance of the whole system. For example, in the tropics acacia species found sparsely on farmland is a good source of timber, fuelwood and gum (Raj et al., 2021), as well as cork oak in the Iberic peninsula of western Europe that provides bark to make corks for the wine industry, in addition to acorns that consumed by pigs yield the famous 'Serrano' and/or 'Iberico' ham. A robust body of scientific literature verifies further the multifaceted benefits of agroforestry (economic, social, agronomic, environmental, etc.), and its applications around the world, in support of an agroecological design for spurring a sustainable agriculture.

CONCLUSION AND FINAL REFLECTIONS

Agriculture continues to remain the culprit and chief villain of all economic activities, emitting in the atmosphere the largest amount of carbon gases that are implicated in climate change (Crippa et al., 2021). It consumes the 70% of all freshwater use and its energy needs derive mostly, from non-renewable sources (~40%), in addition to the one coming from the sun. Massive conversions of land use into crop land and/or pasture are the symptoms of a dysfunctional agriculture that leads the way also in polluting freshwater with residues of pesticides, chemical fertilizers, hormones, antibiotics, and soil from erosion. This nefarious trend in agriculture is expected to grow further within the next three decades, due to a steady rate of population growth that although modest (~1%), adds about 75 million people, to our crowded planet, every year (Springmann et al., 2018). Many agricultural experts continue supporting an intensification of food production, claiming biotechnologies, precision farming, automation and climate smart agriculture, the needed approaches, and tools, that will allow modern society to overcome this challenge and feed 10 billion people by 2050. However, this extractive emphasis of the present agro-industrial model of food production is unsustainable and continues to operate as a major problem and challenge, to climate mitigation and sustainable development.

This is implying that modern agriculture and food supply chains are in a collision course with nature and this hazardous trajectory demands immediate attention and remediation actions. Agroecology provides feasible alternatives for agriculture to avert the calamitous, predicted consequences of an unleashed Anthropocene yet, it involves much more than preserving, or expanding traditional agriculture, while extending food production to urban areas (Altieri MA & Nicholls CI, 2020). A transformation of modern agriculture toward sustainability is more likely to occur by re-establishing more robust links between farmers and consumers because this relationship strengthens local economies and cultures that are foundation forces of any food system (Gliessman S, 2015). A focus on education in food systems sustainability should encompass entirely, the food production, distribution aspects, that in agroecology are inclusive of the economic and socio-cultural aspects of this primary human production sector (Onwueme et al., 2008; Borsari B, 2011). This more holistic vision plan should invest not solely in research but also in education, while striving to reduce poverty, inequalities, violence, and political antagonisms that too often escalate to tragic armed conflicts (within and among countries), destroying the livelihoods of millions and amplifying mass migrations and misery. Access to food and land are sacrosanct rights, which should be honoured, not only to preserve the germplasm of plant and animal species that are pillar food foundations for humanity, but also (and above all), to ensure dignity and respect for every human being.

Although agroecology is on an ascending curve of acceptance as a science, a practice and as a social movement, its establishment is not free from appropriations by industrial agriculture that has started to greenwash its image through the use of persuasive terminology, like climate-smart and/or precision farming, intended to maintain the agribusiness *status quo* in agriculture, that handled by few, gigantic corporations continues to cause misery and displacement from the land of millions of small, dispossessed family farmers (Held L, 2021). For these reasons, agroecologists advise agroecology groups and farmers' organizations to abstain from partnering with private companies, or food corporations (Rosset PM & Altieri MA, 2017). This warning should prevent a co-optation of their work and values by the capitalistic interests of agribusiness, as this model of agriculture remains pervasive across the agroindustry. Another challenge posed by industrial agriculture consists in its persuasive indoctrination of society with illusive narratives to make believe that industrial agriculture is the only way of ensuring cheap, high-quality food to all, in great abundance. Unfortunately, this paternalistic rhetoric remains supported by many researchers, who are employed in the colleges of agriculture of land-grant universities, and who continue to receive generous funding from agribusiness corporations for answering questions that may bring high lucrative gains to the industry through patents an advanced technologies yet, these remain of marginal access, or utility to family farmers (Berry W, 1977).

Dietary changes veering towards eating habits that rely mostly on plant products like fruits, roots and vegetables, coupled by advances in knowledge about agriculture and more emphasis on reducing food waste, are ideal strategies that can reduce GHGs from the food system and mitigate successfully, the global climate (Springmann et al., 2018). However, tangible risks and uncertainty that agriculture in conjunction with other human activities compromise planet Earth's homeostasis persist as a disturbing reality. Nonetheless, a safe corridor of operation is achievable if human activities will be soon constrained within the limits of the planetary boundaries (Rockström et al., 2021). To make this possible, a four-pronged plan for transforming the food system, which was proposed by IPES-Food & ETC Group in 2021 must be enacted without delay (Rockström J & Gaffney O, 2021). This scheme offers a route that could shift trillions of US dollars from agribusiness to food sovereignty, agroecology, and similar programs thus, reducing 75% of GHG emissions generated by food systems, with immediate, benign effects on biodiversity, its preservation, and a slow restoration toward normality of biogeochemical cycles. An effective move in this direction demands for an urgent reallocation of agricultural subsidies from agribusiness corporations to family farmers and peasant cooperatives, or growers' associations who are committed to good stewardship as established by agroecological practices and with standards that are based on carbon sequestration in soils and biodiversity conservation, rather than overproduction (Borsari B & Kunnas J, 2020) and corporative profits (Rosset PM & Altieri MA, 2017). At this critical moment, it is imperative for society to transform itself, beginning with systemic changes to the food system. Shifts undergone by large segments of humanity during the Covid-19 pandemic in 2020, have demonstrated unimaginable resilience by farming systems where agroecology is applied and embraced as established practice in agriculture (Altieri MA & Nicholls CI, 2020). These experiences remain as vivid memories of creativity and solidarity, defining at the end, the benign capabilities and resilience of humanity, while reiterating the potentials of agroecology to lead agriculture and food systems toward a restoration of agrobiodiversity and a unilateral pursuit of sustainability.

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