Fertilizers for Improving the Growth Characteristics and N Uptake of Wild *Rorippa indica* L. Hiern in Different Soil

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ABSTRACT

Rorippa indica L. Hiern is a local vegetable that is widely consumed by Dayak's tribe in Central Kalimantan, Indonesia. It is mostly traditionally cultivated without fertilizers, resulting in low productivity. The research aimed to investigate the effect of fertilizers and soil type on the growth characteristics and N uptake of *R. indica*. The experiment was arranged in a factorial completely randomized design consisting of two factors with four replications. The first factor was fertilizer application (control, 20 t ha^{-1} of chicken manure, and 600 kg ha^{-1} of NPK), and the second was soil type (peat and Ultisol). The results revealed that the interaction of fertilizers and soil type gave a non-significant effect on all variables observed, except N uptake. The application of NPK increased the plant height and number of leaves significantly. Compared to control, the increment was 112.50% and 130.32%, respectively, and chicken manure application increased the dry weight (327.87%), N total (310.16%), and N uptake of plants by 478% in peat soil and 228% in Ultisol. This finding concludes that 20 t ha^{-1} of chicken manure can be applied to increase the productivity of *R. indica*.

Keywords: Inorganic fertilizers, Organic fertilizers, Peat, *Rorippa indica*, Ultisol

ABSTRAK

Rorippa indica L. Hiern merupakan sayuran lokal yang dikonsumsi oleh masyarakat Dayak di Kalimantan Tengah. Sayuran ini tumbuh liar tanpa asupan pupuk dalam budidayanya berakibat pada rendahnya hasil tanaman. Tujuan penelitian ini adalah mempelajari pengaruh pemberian pupuk dan perbedaan tanah sebagai media tumbuh terhadap pertumbuhan dan serapan N dari R. indica. Rancangan penelitian menggunakan rancangan acak lengkap faktorial dan diulang sebanyak 4 kali. Faktor pertama adalah pemupukan (kontrol, 20 t ha^{-1} kotoran ayam, dan 600 kg ha^{-1} NPK), sementara itu faktor kedua adalah tipe tanah yang digunakan (gambut dan Ultisol). Hasil penelitian menunjukkan bahwa tidak terjadi interaksi antara pemupukan dan tipe tanah pada semua parameter pengamatan, kecuali serapan N. Pemberian NPK mampu meningkatkan tinggi tanaman (112.50%) dan jumlah daun (130.32%) dibandingkan kontrol. Aplikasi pupuk kotoran ayam meningkatkan berat kering tanaman (327.87%), N total (310.16%), dan serapan N sebanyak 478% pada tanah gambut dan 228% pada Ultisol. Pemupukan dengan kotoran ayam sebanyak 20 t ha^{-1} dapat diaplikasikan untuk meningkatkan produktivitas R. indica.

Kata kunci: *Pupuk anorganik, Pupuk organik, Gambut, Rorippa indica, Ultisol*

INTRODUCTION

Brassicaceae is a family that includes many important crop plants, ornamentals, and weeds (Liu et al., 2011). The Rorippa Scop. is one of the Brassicaceae, comprising approximately 80 species, including *Rorippa indica* (L) Hiern, *R. palustris* (L) Besser, *R. integrifolia* Boulos (Marzouk et al., 2016), *R. cantoniensis* (Lour.) Ohwi (Liu et al., 2012), *R. fluviatilis* (E.Mey.ex Sond), *R. nudiuscula* (Welcome & Van Wyk, 2019; Moteetee et al., 2019), *R. islandica*, *R. subumbellata* and *R. nasturtium* (Baskin & Baskin, 2014). *R. indica* L. Hiern belongs to the family of Brassicaceae or Cruciferae. The vascular plant (Hwang et al., 2013; Lee et al., 2013; Jang et al., 2013; Yoon et al., 2013) has the common names of watercress and field cress. Many are found in Asia, South and North America (Xu & Deng, 2017), and India, with a dense population (Ananthi & Kumari, 2013). In the various report, *R. indica* was regarded as a wild plant (Bandopadhyay et al., 2013; Nag & Hasan, 2016; Takabayashi & Shiojiri,

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2019;), weed (Hamdani & Nuryanti, 2011; Nasu & Momohara, 2016; Nazir et al., 2016; Sarkar et al., 2016; Hwang et al., 2017), animal forage (Marzouk et al., 2016), phytoremediator (Cui et al., 2013), medicinal plant (Ananthi & Kumari, 2013; Long-Ze et al., 2014; Siew et al., 2014; Zhang et al., 2014; Dutt et al., 2015; Marzouk et al., 2016; Sengupta et al., 2018; Yang et al., 2020; Lin et al., 2021), companion species in the rice field (Kim et al., 2019), and wild edible plant (Moteetee et al., 2019; Iyda et al., 2019).

R. indica is a local vegetable consumed by Dayak's tribe in Central Kalimantan. Leaves of *R. indica* have been used by local people to fulfill their need for sources of vitamins and minerals. They consume the vegetable in clear soup with corn, milk soup, and salad. The vernacular name is segau (Chotimah et al., 2013). *R. indica* is not specifically cultivated, and it tends to grow wild. Their natural habitat is on the roadsides, burned land, valley, riverbanks, wetland, gardens and, rice fields. The *R. indica* also dominates the perennially and seasonally flooded areas as well as flood plain areas (Liu et al., 2020). It grows best on sandy soils, and full sunlight favors better flowering. It has a simple leaf, bright yellow petals, and round seeds, with a flowering age of 46 – 51 days. *R. indica* has jagged leaves, and its taste is slightly bitter. The plant height was around 1.9 and 0.6 m when planted in lowland next to the water and upland, respectively. The seed is brownish-red, with an ovoid shape and a size of 0.8–1 x 0.7–0.8 mm.

The government recognizes the requirement for systematic wild plant species conservation, which pays more attention because wild plant species will be of value for the future for securing this vast reservoir of diversity for agriculture and food security. The wild plants are experiencing widespread genetic erosion and even extinction (Vincent et al., 2013). The germplasm rescue and the land conversion for oil palm plantation and the forest fire every year in Central Kalimantan become a basic consideration for domesticating *R. indica* to improve food security significantly. Amelioration is our target to underpin their genetic adaptation to a diverse range of habitats.

Based on personal communication with farmers, the decrease in *R. indica* yields could reach 0.25 tons per ha due to constraints in the use of growing media. The abundant soil in Central Kalimantan is peat and Ultisol. These soils are sometimes grouped as marginal soils due to their acidity and low natural fertility (Prasetyo et al., 2016; Maftu'ah & Nursyamsi, 2019). Fertility can be improved by amelioration applications, including inorganic and organic fertilizers. Alakhyar et al., (2019) investigated the effects of six organic fertilizers concentration of 0%, 20%, 40%, 60%, 80%, and 100% on the *Brassica juncea* L production, and the optimum concentration obtained was 70.85% to produce a weight of 73 g per plant. The attempts to develop a prominent yield were conducted by Mir et al., (2010) using the combination of phosphorous and potassium on the mustard yield, and 60 kg P_2O_5 ha^{-1} and 60 kg P_2O_5 + 60 K_2O ha^{-1} were proven to improve the seed yield. Therefore, fertilizer use is the key factor in maintaining soil quality, enhancing soil nutrients, and increasing crop production. There is only preliminary information on the fertility requirement of wild plant *R.indica*. Optimum nutrients amount has a major impact not only on crop productivity but also on nutritional value. Hence, the study was conducted to determine the effects of fertilizers (organic and inorganic NPK) and the soil type on the growth characteristics and nitrogen uptake of *R.indica*.

MATERIALS AND METHODS

The research was conducted from January to June 2018 at the Greenhouse of the Department of

Agronomy, University of Palangka Raya (S 2°12'42'' E 113°54'15''). Peat and Ultisol were obtained from Kalampangan Palangka Raya and Pundu Katingan District, taken at a depth of 20 cm. The experiment was arranged in a factorial completely randomized design, consisting of two factors with four replications. The first factor was fertilizers application (control, 20 t ha^{-1} chicken manure, 600 kg ha^{-1} NPK (16-16-16), and the second factor was soil type (peat and Ultisol). The peat soil has soil pH (H_2O) of 3.35, N-total (Kjeldahl) of 0.64%, organic C of 57.01% (Walkey and Black), available P (Bray I) of 165.67 ppm, exchangeable K (NH_4OAc pH 4.8) of 0.63 cmol/kg, exchangeable Ca (NH_4OAc pH 4.8) of 2.11 cmol/kg, and base saturation of 13.09%, respectively. Meanwhile, Ultisol has soil pH (H_2O) of 4.25, total N of 0.17%, organic C of 2.65%, available P (Bray I) of 53.53 ppm, K of exchangeable 0.22 cmol/kg, exchangeable Ca (NH_4OAc pH 4.8) of 0.93 cmol/kg, and base saturation of 9.60%. The chemical properties of chicken manure are 1.39% total N, 872.40 ppm total P, 15752.42 ppm total K, 8549.53 ppm total Ca, and 5366.33 ppm total Mg.

The seeds used were obtained from the farmer in Seruyan District. Before planting, the seeds were planted at the seedbed for 21 days with husk charcoal media, and then planting was done by placing one seedling per polybag. Fertilizers were applied at planting and repeated four times in seven days. Chicken manure was added to as much as 20 t ha^{-1} (227g/5 kg peat/polybag; 74g/12 kg Ultisol/polybag), and NPK was applied to as much as 600 kg ha^{-1} (6.82 g/5 kg peat/polybag; 2.22 g/12 kg Ultisol/polybag) by placing it around 5 cm from root. Watering was carried out twice a day using 250 ml glass. Weeding was manually performed by pulling out the weeds. *R.indica* was harvested 60 days after planting (DAP) by pulling out the whole plant. The observed growth characteristics include plant height, number of leaves, leaf area (measured by leaf area meter), plant dry weight, and total N of tissues measured at 35 DAP and determined by HNO_3-$HClO_4$ wet extraction. N uptake is the total N of tissues multiplied by plant dry weight. The samples for total N of tissues were analyzed at the Soil Laboratory of the University of Lambung Mangkurat. In addition, the chemical properties of soil were analyzed at the Analytical Laboratory of the University of Palangka Raya. The collected data were subjected to ANOVA, followed by LSD test with 5% significance levels using SPSS statistical package.

RESULTS AND DISCUSSION

Chemical properties of soils

The application of organic and inorganic fertilizers increased the chemical properties of both soils (Table 1). Compared to control, the pH, N, P, K, Ca and base saturation of peat increased by 36.72%, 78.13%, 458.22%, 379.37%, 248.82% and 160.35%, respectively, while the increment of Ultisol were 57.65%, 70.59%, 154.08%, 1272.73%, 312.90% and 135.31%, respectively. Generally, soil fertility increased with the application of fertilizers compared to the initial media properties before treatments. The increasing pH due to 20 t ha^{-1} chicken manure and 600 kg ha^{-1} NPK indicated that fertilizer application on *R.indica* could provide plant nutrient content. Increased soil pH affects the increase in negative soil charge. The soil charge of both peat and Ultisol is pH-dependent (Lesbani & Badaruddin, 2012). The functions of negative soil charge are to bind the cations present in the soil, resulting in reduced leaching and enlarged storage capacity of nutrients in the soil. The foregoing is shown by increasing exchangeable K, exchangeable Ca, and base saturation in both types of soil. The base saturation in both types of soil was from 13.09% to 34.08% in peat and 9.60% to 22.59%

Table 1. The chemical properties of soils as affected by fertilizer application

Properties	Peat	Ultisol
pH H20 (1:2,5)	4.58	6.70
Total N (%)	1.14	0.29
Organic C (%)	54.22	0.88
P-Bray I (ppm)	924.8	136.01
Exc. K (cmol/kg)	3.02	3.02
Exc. Ca (cmol/kg)	7.36	3.84
Base Saturation (%)	34.08	22.59

Table 2. The plant height, number of leaves, leaf area of *R. indica* at 35 (DAP) and dry weight as well as N content of tissue as affected by the application of fertilizers

Fertilizers	Plant height (cm)	Leaf number	Leaf area (cm)	Dry weight (g)	N-total tissue (%)
Control	16.79 a	15.63 a	13.70 a	0.61 a	3.11 a
20 t ha-1 chicken manure	31.53 b	32.00 b	21.34 b	2.61 c	3.34 a
600 kg ha-1 NPK	35.68 b	36.00 b	19.85 b	1.49 b	3.38 a
LSD 0.05	5.43	5.74	3.30	0.85	2.72
Soil					
Peat	26.64	26.67	19.34	1.50	3.34
Ultisol	29.35	29.08	17.26	1.64	3.21
LSD 0.05	3.65	3.86	2.22	0.57	1.83

Remarks: Means followed by the same letter sat the same column are not significantly different based on LSD test at a level of α 0.05

in Ultisol, respectively. The rate of increase in pH is also closely related to plant biomass. This can be seen from the significant differences in the dry weight of *R.indica*. In the Ultisol, chicken manure given at a dose of 20 t ha^{-1} produced the maximum plant weight of 2.61g, followed by NPK at 1.49g, while the plants without fertilizer produced the minimum plant dry weight of 0.61 g (Table 2).

The increase in negative soil charge also increased the availability of soil P. The high positive charge in both soils has a strong binding to soil P, causing its availability to be very low. Decreasing the positive charge will release phosphate compounds into the soil. In the Ultisol, the presence of both Al and Fe compounds induces P unavailable to plants due to P compounds being fixed and difficult to release (Khan et al., 2014). The rising pH value results in the declining mobility of metal Al and Fe (Ch'Ng et al., 2014) and the release of fixated P to the soil. In the peat soil, the rising pH value exhibits the decline of the toxic organic acids' activity for plants. An increase in soil pH stimulates soil microorganisms to actively aid in the breakdown of organic matter (Ichriani et al., 2021) into an organic, which is more available to plant growth, such as the availability of P. The soil microorganisms' activity produces phytohormones, vitamins, and amino acids that can release soil P (Chakkaravarthy et al., 2010). Chicken manure contains high total nutrients.

In contrast to other organic fertilizers, chicken manure decomposes relatively quickly. The activity can be diminished by the provision of binding agents, such as ash (Haryoko, 2012). The improvement of soil chemical conditions will provide the best atmosphere for growing media that support plant growth.

Growth characteristics

The interaction effect of fertilizer and soil types was not significant on the growth characteristics. Compared to control, applying organic and inorganic fertilizers increased the growth characteristics of *R. indica* (plant height, number of leaves, leaf

area, dry weight) (Table 2). Moreover, Table 2 shows that the increment of plant height, number of leaves, and leaf area are 87.79%, 104.73%, and 55.77%, respectively, in organically fertilized pots. Meanwhile, those in NPK fertilized pots are 112.51%, 130.33%, and 44.89%, respectively. The highest biomass or dry weight was obtained in the treatment of 20 ton ha^{-1} chicken manure, followed by 600 kg ha^{-1} NPK and control.

The case of low soil fertility is considered as one of the most important constraints on improving crop production, including *R. indica*. Fertilizers can provide sufficient nutrients for good plant growth. The data showed that these treatments had significant effects (Table 2). Therefore, it is concluded that using fertilizers in the *R. indica* cultivation should be encouraged. The use of fertilizers for vegetable crops that belong to the Brassicaceae family was confirmed by Olaniyi & Ojetayo (2011). The slightest growth response of the unfertilized cabbage might be due to the low nutrient availability during the growth period. The vegetable crop performance could be linked to genetic and environmental influences, including climatic conditions, nutrient source, and soil fertility. The use of fertilizers is attributed to the availability of nutrients, thus increasing plant growth. The field experiment by Jankowski et al., (2019) reported that *Camelina sativa* (L.) Crantz, Brassicaceae fertilized with N produced taller, thicker, and more branched shoots. Fertilizer nitrogen higher than 120 kg ha^{-1} is recommended in the C. *sativa* seed production.

The chemical properties of both soil types also showed improvements due to fertilization (Table 1). This is inconsistent with Uka et al., (2013), reporting that inorganic fertilizers, such as NPK, worsen soil degradation, thereby generating higher acidity, nutrient imbalance and low crop yield. Whilst, organic fertilizer promotes the gradual release of nutrients over time. Jankowski et al., (2019) conveyed Brassicaceae's fertilizers and soil fertility needs, previously Cruciferae or Crucifers. Throughout their life cycle, Brassica crops require certain nutrients in varying amounts to support optimal growth and reproduction. The optimal growth and reproduction can be achieved if the soil is healthy. Healthy soil will have a greater capacity to uptake fertilizers, and nutrient uptake will be more balanced. To maintain healthy soil is cultivation practices, such as applying manure and compost, using soil cover, and crop rotation.

The plant height was higher compared to the results obtained by Syahid et al., (2013), who reported that *R.indica* grown in peat soil treated by adding chicken manure combined with charcoal husk resulted in the plant height of 23.4 cm 5 weeks after planting. Both results of the experiment are still shorter evidently if compared to those in their natural habitat. The plant reached 0.6 m in upland and 1.9 m in the lowland next to the water. Table 2 shows that NPK fertilizer plays a role in the first stage of plant growth, especially in the elongation of stems and leaf formation. The role of organic fertilizer is in leaf area development and the formation of plant biomass. This is in line with Uka et al., (2013) research on okra (*Abelmoschus esculentus*). The fastest growth rate occurred in the first three weeks due to NPK fertilizer, while the plants treated with organic fertilizer grew taller from the sixth week up to the end of the experiment in the tenth week. The highest values of plant growth and yield were found in *Raphanus sativus,* an edible root vegetable that belongs to the Cruciferae family, treated with NPK. (Kiran et al., 2016). Syahid et al., (2013) reported that the administration of chicken manure combined with husk charcoal to *R.indica* resulted in a large number of leaves of 9.3. Yuseda (2012) reported that *R.indica* planting in mineral soil produced the highest leaf number of 10.70.

Concerning leaf area expansion, the organic

fertilizer improved the leaf area of *R. indica* at 35 DAP (Table 2). The organic nutrient source has been reported by Lim & Vimala (2012) to improve both vegetable quality and soil chemical, physical, and biological properties. This has an important effect on the high charge of organic matter for retaining nutrients and preparing them available to the plants (Diacono & Montemurro, 2010). The availability of nutrients on plant roots increases plant growth (Uka et al., 2013).

Amelioration with chicken manure at a dose of 20 t ha^{-1} produced maximum dry weight of 2.61 g, followed by those treated with NPK of 1.49 g compared to control (Table 2). Organic manures, like chicken manures, promote microbial degradation and the gradual release of nutrients over time, while NPK results in soil degradation due to loss of inorganic matter, which leads to higher acidity, nutrient imbalance, and low crop yield (Adewole & Ilesanmi, 2012). In the rhizosphere, organic fertilizer can help shape the microbial composition and recruit beneficial bacteria into the rhizosphere (Lin et al., 2019).

N uptake

Both fertilizer applications gave no significant increase in the total N of *R. indica* (Table 2). Moe et al., (2019) declared that nutrient uptake characteristics generally varied with the cultivar, soil type, environment, and fertilizers used. The nutrient content in soil, particularly N, P, and Zn, could also be improved by applying cattle manure on leafy vegetables due to reducing soil acidity and increasing soil electrical conductivity without affecting the growth and yield of the leafy vegetables (Mantovani et al., 2017). Total N in the tissues of *R. indica* impacted by both fertilizers (Table 2) was higher than N contents of *Diplazium esculentum*, the wild edible fern collected from Bangladesh, at 13.97 mg/g (Zihad et al., 2019). Ntuli (2019) also recorded the nutrient content of nine rare wild leafy vegetables consumed by rural communities in northern KwaZulu-Natal from 3.89-6.29% N. The sufficient nitrogen leaf content varies from a low of 2.00 to a high of 5.00% of the dry weight.

The interaction effect of fertilizers and soil type was significant. On average, both fertilizers increased the N uptake of *R. indica* in both soil types. The highest N uptake occurred on *R. indica* treated by organic fertilizer in Ultisol (Table 3). The nutrient uptake by plants is strongly influenced by the level and availability of nutrients in the soil (Nugraha, 2010). Soil organic matter is a predominant source of N crops. The suitability of organic matter to finetune the nutrient supply to the crop requirement is characterized by the fast N availability provided (Tei et al., 2020). Biofertilizer was also recommended for providing N nutrient in lettuce grown in a Ultisol (Stamford et al., 2019).

Table 3. The N uptake (g/plant) of plants as affected by soil types and fertilizers

Fertilizer	Growing media (soil types)	
	Peat	Ultisol
Control	1.24 a	2.49 a
20 t ha-1 chicken manure	7.17 c	8.17 c
600 kg ha-1 NPK	5.44 b	4.65 b

Remarks: Means followed by the same letter sat the same column are not significantly different based on LSD test at a level of α 0.05

CONCLUSION

Application of inorganic and organic fertilizer improved soil properties, growth characteristics, and N uptake of *R. indica* in both soil types. All observed variables were not affected significantly by the type of soil. Compared to control, the application of 20 t ha^{-1} chicken manure increased the dry

weight and N uptake, while the 600 kg ha^{-1} NPK increased plant height and number of leaves. The maximum dry weight (2.61g/pot) and N uptake (8.17 g/plant) were obtained from the application of 20 t ha^{-1} chicken manure (75.17% and 75.70% higher than NPK fertilizer). These results confirm that chicken manure, as an environmentally friendly ameliorant, can be applied to improve the productivity of *R. indica*.

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