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Full Length Article

Study of Green Manure (*Tithonia diversifola* and *Chromolaena odorata*) and NPK Fertilizer Combination on Soil Chemical Properties and Yield of Pakcoy (*Brassica rapa*) in Ultisols

Muhammad Iqbal Fauzan[1*†], Septrial Arafat[1†], Rachmahadi Ichsan Muharam[2] and Rahmat Abdullah[2]

[1]*Department of Agriculture, Faculty of Animal and Agricultural Sciences, Universitas Diponegoro, Jl. Prof H. Soedarto, Tembalang, Semarang 50275, Indonesia*

[2]*Agroecotechnology Study Program, Faculty of Agriculture, Universitas Padjadjaran, Jl. Raya Jatinangor Km 21 Jatinangor 40600 Bandung, Indonesia*

[*]For correspondence: muhammadiqbalfauzan@lecturer.undip.ac.id

[†]Contributed equally to this work and are co-first authors

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Abstract

The Problem with ultisols are it lack nutrients such as nitrogen, phosphorus, and potassium. Ultisols potentially developed into cropland by addressing the existing constraints. This research was conducted to study the effect of the combination of NPK fertilizer with green manure on various soil chemical properties and the yield of pakcoy on ultisols Jatinangor. A Randomized Complete Block design (RCBD) was utilized in this investigation, with eight treatments and four replications, which consist of SO (soil only), SN (NPK 300 kg ha^{-1}), T1 (NPK 300 kg ha^{-1} + 10 t ha^{-1} *Tithonia diversifolia*), T2 (NPK 225 kg ha^{-1} + 15 t ha^{-1} *T. diversifolia*); T3 (NPK 150 kg ha^{-1} + 20 t ha^{-1} *T. diversifolia*), C1 (NPK 300 kg ha^{-1} + 10 t ha^{-1} *Chromolaena odorata*), C2 (NPK 225 kg ha^{-1} and 15 t ha^{-1} *C. odorata*), C3 (NPK 150 kg ha^{-1} + 20 t ha^{-1} *C. odorata*). The results showed that combining NPK with green manure significantly affects soil chemical properties of pH, organic-C, total N, available P, uptake of P, and uptake of N in ultisols. It did not significantly affect exchangeable K and cation exchange capacity (CEC). The best and effective average yield of pakcoy was found in C2 treatment with a yield of 63.75 g. © 2024 Friends Science Publishers

Keywords: *Chromolaena odorata*; NPK compound fertilizer; Pakcoy; *Tithonia diversifolia*; Ultisols

Introduction

Ultisols is Indonesia's second-largest soil order, with a land area of 36.3 million ha or 19.29% of the total land area in Indonesia (BBSDLP 2020). Ultisols are soils that have undergone advanced weathering derived from very acidic parent materials. This soil contains low organic matter, and the structure is not very strong, making it susceptible to erosion (Hardjowigeno 2007).

Infertile soils with intensive nutrient leaching problems, nutrient deficiencies, and acid soil reactions characterize ultisols. Some issues in ultisols are high acidity, Al exchangeability, and low nutrient content, such as the availability of P because Al, Fe, or Mn fix it (Widiatmaka *et al*. 2016; Anggita *et al*. 2018). One of the efforts can be made to increase fertility and add nutrients to ultisols by adding compound NPK and green manure.

Compound NPK fertilizer is a mixed fertilizer generally containing more than one type of plant nutrient, especially N, P and K in one formula (Bijay and Sapkota 2022). The use of chemical fertilizers in Indonesia is still very high and increasing. Indonesia's fertilizer consumption ranges from 10 million tons to 11 million tons in 2017–2021 (APPI 2022), so it is necessary to do ways to reduce the use of chemical fertilizers. Previous experiment, Anggraini *et al*. (2017) used NPK 25-7-7 on pakcoy plant. NPK fertilizer 25-7-7 has advantages compared to other NPK fertilizers. These advantages include nutrient content, characteristics, its role in plants, and ease of application.

Adding organic matter can improve the nutrients N, P, and K's availability. Organic materials that can be given include compost, manure and green manure (Sugiharto and Widawati 2012). Applying green manure to the soil has a good impact on the soil. Green manure is recognized for its ability to enhance soil sustainability through the reduction of soil erosion, improvement of soil's physical characteristics, and the promotion of increased fertility and nutrient retention (Yang *et al.* 2023). Plants will respond positively if the plant media provides suitable conditions for growth and development. Green manure added to the soil benefits plant growth through the decomposition of green manure.

Tithonia diversifolia holds promise as a source of

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organic material due to its substantial biomass production, estimated at approximately 5.6–8.1 tons per/ha/year. The biomass of *Tithonia* is rich in nutrients, comprising 3.5% nitrogen (N), 0.37% phosphorus (P), and 4.1% potassium (K), according to Jama *et al*. (2000). Consequently, the use of *T. diversifolia* has the potential to augment the levels of N, P and K in the soil. Similarly, *C. odorata* can be harnessed as an organic resource, given its composition of 2.65% N and 1.90% K, rendering it a viable source of green manure as well, as indicated by Setyowati *et al*. (2008).

Hafifah *et al*. (2016) reported that applying *T. diversifolia* green manure and cow manure can improve soil's physical and chemical properties and increase cauliflower yield. As a source of soil organic matter, green manure has an essential function in the soil. Aboyeji (2019) stated that green manure increased the vegetative and yield parameter and was comparable to NPK fertilizer. According to Ilori *et al.* (2011), the high rates of leaf senescence and decomposition in *Chromolaena* improve the physical and chemical properties of the soil beneath its canopy by raising and increasing plant nutrition levels.

Research on using green manure, especially *T. diversifolia* and *C. odorata* has not been carried out much. This study aimed to determine the effect of the combination of various doses of NPK compound fertilizer and green manure on soil chemical properties and the best combination of doses of NPK compound fertilizer and green manure on pakcoy yield in ultisols.

Materials and Methods

Experimental set-up

This study was conducted at the greenhouse of the experimental farm of the Agriculture Faculty, Universitas Padjadjaran in Ciparanje, Jatinangor, Sumedang Regency, West Java, with an altitude of ± 700 m above sea level. The greenhouse temperature had been observed daily during the study since the transplanting was conducted. Observations are made three times a day in the morning at 08.00 A.M., noon 12.00 P.M. and afternoon 16.00 P.M. Measurements are taken using a digital thermometer. During the experiment, the average temperature in the greenhouse from morning to evening was 32.99°C. Initial and final soil analyses were conducted at Soil Chemistry Laboratory, Agriculture Faculty, Universitas Padjadjaran. At Ciparanje, the Agriculture Faculty's experimental farm soil samples were taken. Universitas Padjadjaran. The soil sample was taken at a depth of 0 to 20 cm, air-dried at room temperature, and then put into polybags weighing 5 kg each after being filtered through a 2 mm stainless steel sieve. NPK compound fertilizer with 25:7:7 was used in this experiment. Green manures (*T. diversifolia* and *C. odorata*) were taken from around the Universitas Padjadjaran experimental farm and then chopped into small pieces before being used as a treatment. A Randomized Complete Block Design (RCBD) was used in this experiment. Four replicates of each of the following eight treatments were used: SO (soil only), SN (NPK 300 kg ha^{-1}), T1 (NPK 300 kg ha^{-1} + 10 t ha^{-1} *T. diversifolia*), T2 (NPK 225 kg ha^{-1} + 15 t ha^{-1} *T. diversifolia*); T3 (NPK 150 kg ha^{-1} + 20 t ha^{-1} *T. diversifolia*), C1 (NPK 300 kg ha^{-1} + 10 t ha^{-1} *C. odorata*), C2 (NPK 225 kg ha^{-1} and 15 t ha^{-1} *C. odorata*), C3 (NPK 150 kg ha^{-1} + 20 t ha^{-1} *C. odorata*). The experimental set-up is presented in Fig. 1.

Soil analysis

The initial soil analysis is presented in Table 1. The initial soil examination for texture using the pipette method, soil reaction was determined using soil to water mixture 1:5, Organic carbon was extracted using the Walkley and Black method, the cation base and Cation Exchange Capacity (CEC) were extracted using an ammonium acetate ($NH_4CH_3CO_2$) solution pH 7 and total N was extracted using the Kjeldahl method (BPT 2005). Available and total P was measured using the Bray method (Bray and Kurtz 1945). Exchangeable aluminum was extracted using KCl 1 N, the final solutions of Ca and Mg were measured using an atomic absorption spectrophotometer, meanwhile, K and Na was measured using a flame emission spectrophotometer (Page *et al*. 1982).

Soil samples for final soil analysis were taken at the time of harvest by collecting soil from the polybags in the plant root zone area. Soil samples from each polybag were then thoroughly mixed and analyzed in the laboratory with the same method in initial soil analysis.

NPK fertilizer and green manure application

Green manure characteristics are presented in Table 2. The application of green manure was carried out after the soil was put into polybags. The amount of soil placed into the polybag was 5 kg. The condition of green manure was fresh, where the part of the plant used as green manure was immersed in the soil and mixed thoroughly. Green manures (*T. diversifolia* and *C. odorata*) were applied into polybags 14 days before planting by weighing fresh green manure according to treatment, then chopping it into small pieces, and then mixing it evenly into the soil so that nothing appears on the ground. Inorganic fertilizer given to pakcoy is in the form of NPK compound fertilizer at a predetermined dose. The NPK compound fertilizer was provided when planting by making a hole 5 cm deep next to the plant.

After 14 days, the polybags were planted with pakcoy plants previously sown in portrays, with the composition of the soil, husk charcoal, and compost in a ratio of 1:1:1 for two weeks. Pakcoy plants were harvested 40 days after transplanting (DAT). The characteristics of plants that can be harvested are that the lower leaves have touched the ground and are starting to turn yellow, the leaves have

Table 1: Soil chemical properties in all treatments before the experiment

Parameters	Value
Physical Properties	
Texture	
Sand (%)	4
Silt (%)	29
Clay (%)	67
Chemical Properties	
C (%)	2.2
N (%)	0.2
C/N	13
CEC (cmol kg^{-1})	20.6
Available P (mg 100 g^{-1})	1.8
Total P (mg 100 g^{-1})	5
Total K (mg 100 g^{-1})	11.6
Base saturation (%)	54.1
Available Mn (mg kg^{-1})	227.5
Exchangeable base (cmol kg^{-1})	
Ca	7.9
Mg	4.1
K	0.4
Na	0.3
Exchangeable H (me 100 g^{-1})	0.5
Exchangeable Al (me 100 g^{-1})	0.6
pH (H_2O)	5.9
pH (KCl)	4.2

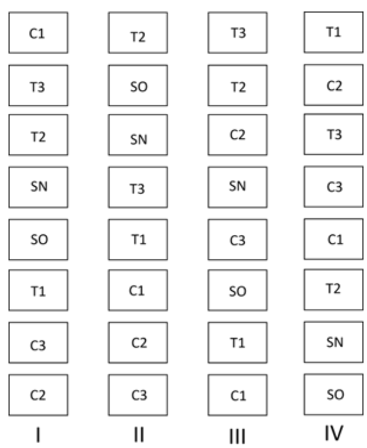

Fig. 1: Experimental set-up. SO (soil only), SN (NPK 300 kg ha^{-1}), T1 (NPK 300 kg ha^{-1} + 10 t ha^{-1} *Tithonia diversifolia*), T2 (NPK 225 kg ha^{-1} + 15 t ha^{-1} *Tithonia diversifolia*); T3 (NPK 150 kg ha^{-1} + 20 t ha^{-1} *Tithonia diversifolia*), C1 (NPK 300 kg ha^{-1} + 10 t ha^{-1} *Chromolaena odorata*), C2 (NPK 225 kg ha^{-1} and 15 t ha^{-1} *Chromolaena odorata*), C3 (NPK 150 kg ha^{-1} + 20 t ha^{-1} *Chromolaena odorata*)

spread evenly, and the plant is ± 20 cm high. Harvesting was done in the morning to ensure the freshness of the plants was preserved.

Data analysis and statistics

Analysis of variance (ANOVA) was used to assess the significance of the treatments with a significance level of 5%. Significantly different variables were further tested using the DMRT test using SPSS Statistics version 22.

Results

Soil chemical properties

The pH value for all treatments is listed in Table 3. We found the highest pH value in C2 (6.19). On the other hand, the lowest pH value was found in SN (5.54) but it was not statistically significant relative to all treatments except C2 (6.19) (Table 3).

Available P for all treatments is listed in Table 3. The highest available P was shown in C1 (8.15 mg kg^{-1}) but was not statistically significant relative to T1 (7.22 mg kg^{-1}) and C3 (7.51 mg kg^{-1}) (Table 3). Treatment SO (soil only) had the lowest available P (3.44 mg kg^{-1}) but was not statistically significant with SN (4.41 mg kg^{-1}).

The organic C value for all treatments is listed in Table 3. The Organic-C value in SO was statistically significant relative to other treatments. T1 and T2 showed no statistically significant relative to T3, C1 and C3 (Table 3). Organic-C in T2, T3, and C3 treatments were higher than all treatments. All green-manure treatments had higher organic-C than SO and SN (Table 2), demonstrating that green manure balances for the soil organic-C.

The total nitrogen value for all treatments is listed in Table 3. In the total N parameter, C3 was statistically significant relative to SO (Table 3); the highest total nitrogen was shown in C3 (0.28%) and statistically significant relative to SN, T1, T3, and C1. On the other hand, the lowest total nitrogen was shown in SO (0.21%) but not statistically significant relative to SN, T1, T2, T3, C1 and C2.

Nutrient uptake (P and N) for all treatments is listed in Table 3. The highest uptake of P was found in C1 (16.48 mg plant^{-1}) but not statistically significant relative to T1 (14.60 mg plant^{-1}) and C2 (15.37 mg plant^{-1}) (Table 3). The lowest P uptake was observed in SO (2.37 mg plant^{-1}) and was statistically significant relative to other treatments. N uptake values varied greatly (Table 3). The SO treatment showed a low N uptake value (1.51 mg plant^{-1}) and was statistically significant relative to other treatments. Whereas the treatment using the highest dose of *T. diversifolia* and moderate dose of *C. odorata*, had the highest N uptake (17.00 and 17.01 mg plant^{-1}, respectively) among all the treatments and these treatments were statistically significant relative to other treatments.

Exchangeable K and CEC for all treatments are listed in Table 3. We found no significant difference in exchangeable K and CEC analysis (Table 3). However, according to the analysis's findings, the CEC value in NPK and green manure combination treatment was higher than the SO (soil only) treatment.

Plant growth and yield of pakcoy

The result of observations of plant height during the experiment is presented in Fig. 2. At 1 week after transplanting (WAT), the growth in plant height was relatively uniform; there was no significant difference in plant height relative to SO, with an average of 6.5 cm. Variations in the plant height began to appear at 4 and 5 WAT. The average height at 4 WAT was 17.5 cm and at 5 WAT was 19.5 cm. C1 showed the best response to plant height at 5 WAT was 23.5 cm, while the lowest was SO *i.e.*, 6 cm. SO did not get additional nutrients from fertilizer and only from the soil.

The result of observations of the number of leaves during the experiment is presented in Fig. 3. It shows that there is an addition of leaves every week. At 1 WAT there was still no difference in the number of leaves in each treatment, whereas at 3 WAT there was a difference in the number of leaves in several treatments. C1 has the highest number of leaves, namely 12. The treatment with the least number of leaves was SO with only four.

The average yield of pakcoy is listed in Table 4. The highest total yield was in C1 (66.74 g) but was not statistically significant relative to T1 and C2. The lowest total yield was in SO (26.64 g) but was not statistically significant relative to SN and T3.

The average root weight of pakcoy is listed in Table 5. The highest total root weight was observed in C1 (7.02 g) but was not statistically significant relative to T1. The lowest total root weight was in SO (1.14 g) but was not statistically significant relative to C2, C3, T2, T3 and SN.

Discussion

The Application of NPK fertilizer can cause soil pH to decrease. The lowest pH value in SN is presumably because of using only NPK fertilizer without being given organic matter. NPK fertilizer can lower soil pH because NPK fertilizer contains sulfur and ammonium, which hydrolyzes to produce H^+ ions which causes soil pH to fall (Starast *et al*. 2003). In addition, a decrease in pH value can occur due to adding organic matter. Hafifah *et al.* (2016) stated that providing organic matter can increase or even decrease soil pH, depending on the type of organic matter supplied. The increase in pH value is related to the anion exchange reaction of organic acids from the decomposition of organic matter with free OH^- thereby increasing OH^- ions in the soil. In addition, the increase in pH value is also caused by the decomposition of green manure, which produces organic acids that can bind sources of soil acidity, such as Al and Fe, to reduce soil acidity. According to Lehmann and Kleber (2015), organic matter weathering produces humic, fulvic, and other organic acids. These organic acids can bind metals such as Al and Fe, reducing soil acidity. Adding organic matter to acid soils was reported to increase soil pH and reduce soil exchange Al (Ch'ng *et al*. 2014).

Neina (2019) stated that the simple result of the overhaul of organic matter is in the form of basic cations such as Ca, Mg, K and Na so that the release of alkaline cations into the soil solution will cause the soil to contain sufficient amounts of these cations and will eventually increase the soil pH. Decomposed organic material has the potential to boost the reactivity of OH^- ions originating from carboxyl (-COOH) and hydroxyl (-OH) groups. These OH^- ions serve to counterbalance the presence of H^+ ions in the soil solution. As per the findings of Bayer *et al.* (2001), the pH fluctuations in soil are directly tied to the concentrations

Table 2: Green manures chemical characteristics for the experiment

Parameters	*Tithonia diversifolia*	*Chromolaena odorata*
C (%)	46.53	41.34
N (%)	3.47	4.38
C/N	13	9
Total P (mg 100 g^{-1})	3.76	2.44
Total K (mg 100 g^{-1})	1.7	0.41

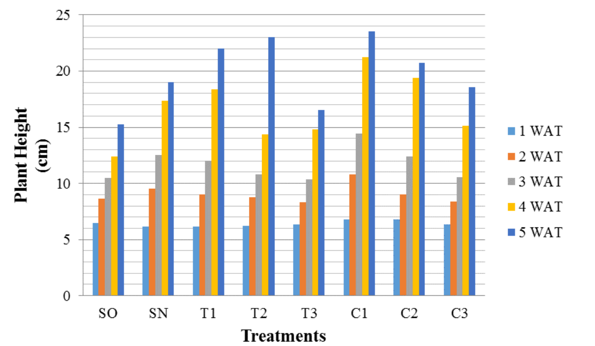

Fig. 2: Average plant height for each treatment. WAT means Week After Transplantation. SO (soil only), SN (NPK 300 kg ha^{-1}), T1 (NPK 300 kg ha^{-1} + 10 t ha^{-1} *Tithonia diversifolia*), T2 (NPK 225 kg ha^{-1} + 15 t ha^{-1}*Tithonia diversifolia*); T3 (NPK 150 kg ha^{-1} + 20 t ha^{-1}*Tithonia diversifolia*), C1 (NPK 300 kg ha^{-1} + 10 t ha^{-1} *Chromolaena odorata*), C2 (NPK 225 kg ha^{-1} and 15 t ha^{-1} *Chromolaena odorata*), C3 (NPK 150 kg ha^{-1} + 20 t ha^{-1} *Chromolaena odorata*)

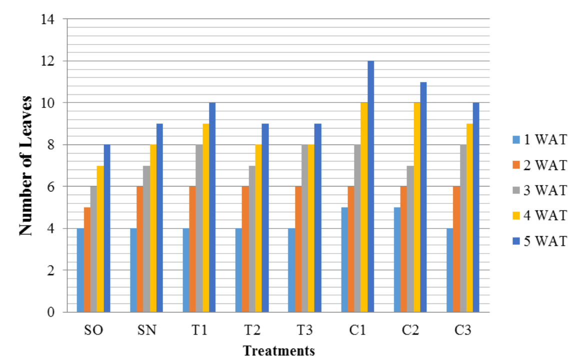

Fig. 3: Average number of pakcoy leaves for each treatment. WAT means Week After Transplantation. SO (soil only), SN (NPK 300 kg ha^{-1}), T1 (NPK 300 kg ha^{-1} + 10 t ha^{-1} *Tithonia diversifolia*), T2 (NPK 225 kg ha^{-1} + 15 t ha^{-1}*Tithonia diversifolia*); T3 (NPK 150 kg ha^{-1} + 20 t ha^{-1}*Tithonia diversifolia*), C1 (NPK 300 kg ha^{-1} + 10 t ha^{-1}*Chromolaena odorata*), C2 (NPK 225 kg ha^{-1} and 15 t ha^{-1} *Chromolaena odorata*), C3 (NPK 150 kg ha^{-1} + 20 t ha^{-1} *Chromolaena odorata*)

Table 3: Soil chemical properties in all treatments after the experiment

Treatment	pH	Organic-C (%)	Total N (%)	Available P (mg kg^{-1})	Exchangeable K (cmol kg^{-1})	CEC (cmol kg^{-1})	Uptake of P (mg plant^{-1})	Uptake of N (mg plant^{-1})
SO	5.97 ab	2.44 a	0.21 a	3.44 a	0.31 a	20.95 a	2.37 a	1.51 a
SN	5.64 a	2.84 b	0.21 a	4.41 ab	0.21 a	21.68 a	10.35 c	14.69 c
T1	5.93 ab	2.93 bc	0.25 ab	7.22 d	0.35 a	20.77 a	14.60 d	17.00 d
T2	5.74 a	3.08 bc	0.23 ab	6.24 c	0.43 a	21.73 a	10.45 c	10.18 b
T3	5.85 a	3.23 c	0.21 a	5.76 c	0.32 a	21.01 a	5.17 b	11.41 b
C1	5.79 a	3.17 c	0.21 a	8.15 d	0.26 a	22.60 a	16.48 d	10.19 b
C2	6.19 b	2.85 b	0.27 ab	5.28 bc	0.36 a	21.90 a	15.37 d	17.01 d
C3	5.97 ab	3.20 c	0.28 b	7.51d	0.32 a	23.51 a	4.70 b	11.61 b

Remark: SO (soil only), SN (NPK 300 kg ha^{-1}), T1 (NPK 300 kg ha^{-1} + 10 t ha^{-1} *Tithonia diversifolia*), T2 (NPK 225 kg ha^{-1} + 15 t ha^{-1}*Tithonia diversifolia*); T3 (NPK 150 kg ha^{-1} + 20 t ha^{-1}*Tithonia diversifolia*), C1 (NPK 300 kg ha^{-1} + 10 t ha^{-1}*Chromolaena odorata*), C2 (NPK 225 kg ha^{-1} and 15 t ha^{-1} *Chromolaena odorata*), C3 (NPK 150 kg ha^{-1} + 20 t ha^{-1}*Chromolaena odorata*)

Table 4: The combination effect of NPK fertilizer and green manure on the pakcoy's average yield in each treatment

Treatment	Pakcoy's Yield (g plant^{-1})
SO	29.18 a
SN	46.50 b
T1	60.51 c
T2	47.30 b
T3	27.22 a
C1	66.74 c
C2	63.75 c
C3	47.31 b

Remark: SO (soil only), SN (NPK 300 kg ha^{-1}), T1 (NPK 300 kg ha^{-1} + 10 t ha^{-1} *T. diversifolia*), T2 (NPK 225 kg ha^{-1} + 15 t ha^{-1}*T. diversifolia*); T3 (NPK 150 kg ha^{-1} + 20 t ha^{-1}*T. diversifolia*), C1 (NPK 300 kg ha^{-1} + 10 t ha^{-1} *C. odorata*), C2 (NPK 225 kg ha^{-1} and 15 t ha^{-1} *C. odorata*), C3 (NPK 150 kg ha^{-1} + 20 t ha^{-1} *C. odorata*)

Table 5: The combination effect of NPK fertilizer and green manure on the pakcoy's average root weight in each treatment

Treatment	Pakcoy's Root Weight (g)
SO	1.14 a
SN	2.08 a
T1	5.96 b
T2	1.66 a
T3	1.73 a
C1	7.02 b
C2	1.30 a
C3	1.66 a

Remark: SO (soil only), SN (NPK 300 kg ha^{-1}), T1 (NPK 300 kg ha^{-1} + 10 t ha^{-1} *T. diversifolia*), T2 (NPK 225 kg ha^{-1} + 15 t ha^{-1}*T. diversifolia*); T3 (NPK 150 kg ha^{-1} + 20 t ha^{-1} *T. diversifolia*), C1 (NPK 300 kg ha^{-1} + 10 t ha^{-1} *C. odorata*), C2 (NPK 225 kg ha^{-1} and 15 t ha^{-1} *C. odorata*), C3 (NPK 150 kg ha^{-1} + 20 t ha^{-1} *C. odorata*)

of H^+ and OH^- ions. When the concentration of H^+ ions in the soil solution rises, the pH decreases, whereas an increase in the concentration of OH^- ions elevates the pH. Decomposed organic material can produce OH^- ions, which, in turn, serve to neutralize the effects of H^+ ions.

Table 3 shows that *C. odorata* treatment at the highest rate got the highest available P value. *C. odorata* can chelate Mn, which binds P so that P goes into the solution to become available P in the soil. C1 got the highest available P because *C. odorata* contains organic matter and P-availability is high enough to increase plant nutrients. Treatment SO (soil only) had the lowest available P value of 3.44 mg kg^{-1} but was not statistically significant with SN. In SN, green manure was not given to the soil, so the increase in available P did not differ much from SO. SO had a low available Phosphorus because it was not given NPK fertilizer and green manure. It might be Mn still bound P and available P in the soil was still small or not yet available. Habi *et al.* (2018) stated that the main issue with phosphorus is its low availability to plants due to the fixation of P adsorbing ions in the soil, such as Al^{3+}, Fe^{2+} and Mn^{2+}. Under acidic pH conditions, elements like Fe and Al can render phosphorus unavailable for plants. According to Stevenson (1982), although organic fertilizers are slower to become available, their application can aid in releasing phosphate bound with Al and Fe into a soluble form. The Mn content in ultisols Jatinangor is higher when compared to Fe. This high Mn content causes the binding of P by Mn to be more significant when compared to Fe. The reaction formed by this bond is $Mn(OH)_2H_2PO^{-4}$, acids so that Mn metal ions can release P and consequently increase soil pH. The increase in available P is presumably due to P from NPK fertilizer being available more quickly, so plants can uptake it. NPK fertilizer contains P element in the form of P_2O_5, with as much as 7% available, so adding P fertilizer will increase the amount of available P in the soil. The increase in soil-available P is caused by applying P fertilizer, which has a slow solubility, so its availability remains high until harvest time (Dharmayanti *et al.* 2013). The application of green manure also caused the increase in available P. It is known that *T. diversifolia* contains 3.76% P, while *C. odorata* contains 2.44% P (Table 2). Both of these green manures have the potential to augment the current phosphorus (P) nutrients in the soil and can substantially impact the availability of P. The increase in available P in Ultisols was due to the direct influence of P fertilization, with the greater the dose of NPK fertilizer and organic matter given, the greater the P content in the soil. The increase in uptake of P was shown in T1, C1 and C2 due to the addition of *T. diversifolia*, *C. odorata* and NPK fertilizer, which can increase nutrients in the soil so that uptake of P increases.

In this experiment, all green-manure treatments had higher organic-C than SO and SN (Table 3), demonstrating that green manure balances for the soil organic-C. Dong *et al*. (2021) found that green manure can compensate for such organic outputs and improve soil nitrogen content. Applying organic matter as green manure to the soil can play a double role because it can improve the soil's physical, chemical, and biological properties (Hafifah *et al*. 2016). The role of applying organic matter such as green manure to soil biological properties, among others, is being able to increase the activity of microorganisms in the soil so that the activity of microorganisms in decomposing organic matter also increases, thus the nutrients contained in the soil become available to plants (Dong *et al*. 2021).

In the total N parameter, C3 was higher compared to the other treatments. This higher value is presumed to be due the fact that treatment C3 provides a high level of nitrogen compared to other treatment combinations due to the addition of nutrients through fertilization and sufficient doses that can increase the total N in the soil directly. The improvement in the soil's ability to deliver nitrogen is associated with the effectiveness of organic materials in supplying nitrogen to plants. According to Mengel and Kirkby (2001), when there is an increase in macro-nutrients in the soil, it results in an enhanced capacity for plant uptake, and this is concurrent with the development of organic compounds within plant tissues. We assumed C2 as the best treatment in the N uptake parameter due to fewer NPK fertilizer doses and more green manure doses than T1.

According to the findings of the analysis, the soil treated with NPK fertilizer and green manure combination had a greater CEC value (Table 3) than the SO (soil only) treatment. The amount of organic matter in the soil itself is one of the elements that determine the CEC value. The value of CEC may rise with the addition of organic matter to the soil. One of the key elements affecting soil CEC levels is organic matter since it has a strong enough negative charge to draw in positively charged cations. High levels of organic matter in soils are also associated with high CEC values (Aprile and Lorandi 2012). According to Chowdhury *et al*. (2021), an increase in organic matter in the soil will be followed by an increase in the cation exchange capacity of the soil itself. Due to the presence of organic matter, hydrogen cations are released as the pH rises, leaving behind negatively charged particles that will eventually turn into cations and be prepared for exchange. The humification process will turn organic materials into humus colloids. Humus is a weathered organic substance with colloidal properties that can bind cations, exchange ions, and absorb water molecules. This humus colloid is subsequently converted into cationic particles that can be exchanged. Clay cannot bind as many ions as humus colloids can at the same weight (Alemayehu and Teshome 2021). The average CEC value of all treatment combinations showed a greater value than the results in the initial soil analysis (Table 1). However, there was no statistical difference between the treatments using green manure and NPK fertilizer. The initial soil analysis found that the soil CEC value was 20.55 cmol kg^{-1}. This shows that the combination treatment of NPK fertilizer and green manure can improve the CEC value of the soil.

The exchangeable K value of the soil is influenced by the type of clay minerals and the ion exchange capacity of the soil. Most of the K^+ ions in the soil solution can be lost due to leach or uptake by plants in the form of K^+ ions. The soil's ability to hold the applied K element is highly dependent on the CEC value of the soil itself. Soils with high CEC values can retain K. The K element added from fertilization will ionize into K^+ ions in the soil solution or become ions bound to clay exchange complexes; if the K content in the soil is low, the K^+ ions on the clay's surface will be released and dissolved in the soil solution (Bell *et al*. 2021). Because NPK fertilizer contains K that can be metabolized and transformed into K^+ ions that plants can exchange and assimilate, it can raise the exchangeable K value in the soil. Adding green manure can also increase nutrient availability by mineralizing organic matter (Valadares *et al*. 2016).

Nitrogen levels in the soil and plant uptake of nitrogen can both be increased by applying NPK fertilizers and organic fertilizers. NPK fertilizer plays a role in providing nitrogen, phosphorus and potassium that plants require since they are crucial for the development of plant cells and tissues. Additionally, green manure can serve as a nitrogen supply, soil improver, and buffer (Dabin *et al.* 2016). Because it increases the soil's availability of nitrogen nutrients, organic matter in green manure with relatively high N nutrients can also raise crop yields (Rayns *et al.* 2010). Zhang *et al.* (2023) stated that applying green fertilizer can increase total N and K in the soil, thereby increasing crop yields. The highest root weight and harvest yield in treatment C1 are due to the application of the highest dosage of NPK fertilizer and the addition of *C. odorata*. However, C2 has the most effective harvest yield because it is not statistically significantly relative to C1. Rukmana (2011) stated that a lack of nitrogen will hinder plant growth, causing the plants to become stunted and resulting in low shoot production in pakcoy. According to Nathania *et al*. (2012), fresh root weight is closely related to the growth and development of roots in the soil and is also associated with the yield.

Adding organic matter can support plant growth by improving soil chemical conditions, including pH. Organic matter can play a role in increasing pH, pakcoy requires a pH value between 4.8–8.5 (Hannaway and Larson 2004). Based on the experimental results, the pH value in this study ranged from 5.64 to 6.19, making it suitable for pakcoy plants. By enhancing soil structure, organic matter also boosts the soil's capacity to hold water (Assefa and Tadesse 2019). Water availability in the soil significantly influences plant fresh weight because 80–90% of the mass of metabolically active plant tissue is made up of water (Filipović 2021).

Conclusion

NPK and green manure significantly affected pH, organic-C, total N, available P, uptake of P, uptake of N, and yield of pakcoy in ultisols Jatinangor. Cation exchange capacity (CEC) and exchangeable K were not significantly affected. Treatment C2 gave the most effective yield because it used a moderate NPK fertilizer rate and was not statistically significant to C1, which used a high NPK dosage. This study shows that the application of green manure can improve some soil chemical properties in ultisols and has potential to reduce the use of chemical fertilizers. Further research is needed with different types of green manure and a wider range of dosages, as well as the effects of the combination of compound NPK fertilizer and green manure on pakcoy plants conducted in experimental field plots.

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Author Contributions

MIF, SA, RIM and RA planned the experiment, interpreted the results, made the write-up, statistically analyzed the data, and made illustrations.

Conflicts of Interest

No authors have disclosed any conflicts of interest.

Data Availability

Data presented in this study will be available on a fair request to the corresponding author.

Ethics Approval

Not applicable to this paper.

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