Available online at:
http://journal.unila.ac.id/index.php/tropicalsoil
DOI: 10.5400/jts.2024.v29i3.159-166

The Effect of Trichoderma on N, P, K Soil and Corn Plants

Jauhari Syamsiyah*, Sri Hartati, Ganjar Herdiansyah, Siti Maro'ah and Rizkia Aufa Nurrahma

*Faculty of Agriculture Sebelas Maret University Surakarta, Ir. Sutami street 36A, Kentingan Surakarta, Indonesia,*e-mail: ninukts@staff.uns.ac.id*

Received 11 September 2023, Revised 26 January 2024; Accepted 26 April 2024

ABSTRACT

The use of Trichoderma is one effort to manage healthy and environmentally friendly plants. This fertilizer is part of organic fertilizer; which farmers do not widely practice yet. This fertilizer has an impact that can increase nutrients and soil fertility. This study examined the impact of using Trichoderma in combination with NPK fertilizer on soil nutrient, nutrient uptake, and growth of corn plants. A Completely Randomized Block Design consisting nine treatments with three replicates was applied. The treatments were Control (A), standard NPK (Urea 350 kg ha^{-1}, SP-36 200kg ha^{-1} and KCl 75kg ha^{-1}) (B), ¼ NPK + 5 kg ha^{-1} Trichoderma (C), ½ NPK + 5 kg ha^{-1} Trichoderma (D), ¾ NPK + 5 kg ha^{-1} Trichoderma (E), 1 NPK + 5 kg ha^{-1} Trichoderma (F), ¾ NPK +1.25 kg ha^{-1} Trichoderma (G), ¾ NPK +2.5 kg ha^{-1} Trichoderma (H), ¾ NPK + 3.75 kg ha^{-1} Trichoderma (I). The results showed that NPK fertilizer accompanied by Trichoderma increased soil total N by 84.21%, available P by 36.25%, and available K by 142.22%. The same treatment also increased corn plants' N, P, and K nutrients by 52.71%, 106%, and 61.53%. The growth of maize plants from applyingTrichoderma up to 5 kg ha^{-1} has not reduced the use of NPK fertilizer yet. However, applying Trichoderma could improve soil fertility.

Keywords: Corn plants, nutrient availability, trichoderma

INTRODUCTION

The earth's population continues to grow and is expected to reach 9 billion by 2025. Due to population growth, mass food production is required to meet the food demand (Raza et al., 2019). Therefore, food availability must be increased while ensuring that food supplies are produced sustainably without compromising the resources provided by nature. Intensification programs developed to meet food demand require high external inputs such as chemical fertilizers and pesticides. It will result in various adverse impacts such as environmental damage, such as water shortages, destruction of biodiversity, increased greenhouse gas levels, and decreased soil fertility, which threaten agricultural productivity and food security (Pandey et al., 2017). One way to improve crop production and increase resistance to various environmental stresses is by utilizing microbes in the soil. The microbe that widely used is Trichoderma. However, it has not be widely practiced by farmers yet. Trichoderma fertilizer is an organic fertilizer that has benefits to plant growth, increases nutrients, and improves soil fertility. Trichoderma is a fungus found in soil and is widely distributed in different parts of the world (Rodríguez et al., 2020); it is currently used in agriculture. It is inseparable from its role in regulating pathogens through metabolic substances, decomposing organic matter to increase soil fertility (Kusparwanti et al., 2022), increasing nitrogen use efficiency and photosynthetic efficiency of plants, and indirectly playing a role in improving soil structure indirectly (Amir and Dermawan, 2019). Trichoderma colonization ability expands the contact area between the rhizosphere and the soil and also increases the secretion of enzymes such as sucrase, urease, phosphatase, and organic acids (Isnaini et al., 2012; Halifu et al., 2019). Various studies have highlighted the role of Trichoderma in stimulating different plant growth-promoting substances (Singh et al., 2019), biological control in soil (Pratama, Mardhiansyah, and Oktorini, 2015), increasing photosynthesis (Oktasari et al., 2021), increasing nutrient uptake by secreting organic acids to dissolve minerals and activate nutrients in the soil (Halifu et al., 2019). This study examined the impact of using Trichoderma in combination with NPK fertilizer on nutrient conditions, nutrient uptake, and growth of corn plants.

MATERIALS AND METHODS

Site description

Field research was conducted in Trayu Village, Banyudono, Boyolali, Central Java (Figure 1). Soil type is Inceptisols. The research location is an agricultural area with food crop commodities, including corn and rice. Corn production in Banyudono District is around 6.82 t ha^{-1} (BPS Boyolali, 2022). Trayu Village has relatively high rainfall, namely 2000 mm yr^{-1}.

The research conducted from May to August 2022. A Randomized Completely Block Design (RCBD) with three replications were applied. The treatments applied were were A = control, B = standard NPK, C = ¼ NPK + 1 Trichoderma, D = ½ NPK + 1 Trichoderma, E = ¾ NPK + 1 Trichoderma, F = 1 NPK + 1 Trichoderma, G = ¾ NPK + 1/4 Trichoderma, H = ¾ NPK +1/2 Trichoderma, I = ¾ NPK + 3/4 Trichoderma as completely described in Table 1.

Experimental design

The research included preparation, planting, fertilization, maintenance, observation, and harvesting. Preparation was done by making a 20 m^2 plot of land and arranging it according to the experimental layout. Corn seeds were planted by digging the soil to a depth of ± 3 cm. Basic fertilizers (Urea, SP-36, KCl) were applied during planting. Urea fertilization was carried out three times which was at planting time, 14 days after planting (DAP), and 28 DAP. Trichoderma fertilization is carried out at 7 DAP. Fertilizers were given according to the dosage for each treatment, as seen in Table 1. Maintenance carried out in the field includes watering, replanting, thinning, weeding, and controlling pests and diseases. Observations of corn plant growth were carried out at 2, 4, 6, 8, and 10 DAP, including plant height, number of leaves, and stem diameter.

The soil used for the experiment had a pH of 6.1, total N 0.09%, available-P 6.36 mg kg^{-1}, available exchangeable-K 0.4 cmol (+) kg^{-1}, and organic-C 0.5%. Soil samples were taken at a depth of 0-20 cm when the plants reached the maximum vegetative phase, and at the same time, plant samples were taken on the fifth leaf from the top. Soil properties observed included total-N (Kjehdahl method), available-P (Olsen method, this suits high pH soils), available-K (25 % HCl Extract method, measures total K_2O), plant NPK using the Kjeldhal method for N, Wet Soaking with HNO_3 and $HClO_4$ for P and K.

Data analysis

A one-way ANOVA (analysis of variance) test was used to determine the effect of treatment on nutrient levels in soil and plants. If there is a

Figure 1. Research site.

Table 1. Treatment structure.

Code	Treatment	Trichoderma ($Kg\ ha^{-1}$)	NPK fertilizer ($Kg\ ha^{-1}$) Urea	SP-36	KCl
A	Control	0	0	0	0
B	NPK standard	0	350	200	75
C	¼ NPK + 1 Trichoderma	5	87.5	50	18.75
D	½ NPK + 1 Trichoderma	5	175	100	37.5
E	¾ NPK + 1 Trichoderma	5	262,5	150	56.25
F	1 NPK + 1 Trichoderma	5	350	200	75
G	¾ NPK + ¼ Trichoderma	1.25	262.5	150	56.25
H	¾ NPK + ½ Trichoderma	2.5	262.5	150	56.25
I	¾ NPK + ¾ Trichoderma	3.75	262.5	150	56.25

significant effect, then continued by Contrast orthogonal to distinguish between variable treatments. Correlation tests to determine the relationship between the observed variables were also done. Parameters observed included plant growth (number of leaves, height, and stem diameter) and nutrients (N, P, K) in soil and plant tissues.

RESULTS AND DISCUSSION

The soil used for the experiment has the chemical properties as shown in Table 2.

Table 2 shows that the soil at the research site is infertile. According to (Hardjowigeno, 2003), the soil is said to be infertile, seen from a slightly acid pH and then followed by a low content of total N, available P, organic C, and exchangeable K. pH can be an early indicator in assessing soil fertility.

The application of Trichoderma with NPK fertilizer significantly affected soil total N, soil available P, soil available K, soil organic C, soil pH, and N, P, K of plant tissues.

The results of the orthogonal contrast test in Table 3 indicate a highly significant difference between the application of NPK fertilizer, as well

Table 2. Preliminary analysis of the Inceptisols in the research location.

No	Parameters	Method	Unit	Result	Level
1	pH H_2O	Potentiometric	-	6.1	Slightly acid
2	pH KCl	Potentiometric	-	5.8	Slightly acid
3	Organic C	Walkley and Black	%	0.5	Very low
4	Total N	Kjeldahl	%	0.09	Very low
5	Available P	Olsen	ppm	6.36	Low
6	Available K	Extract HCl	me $100g^{-1}$	0.4	Medium

Table 3. Soil chemical properties.

Treatment	Total N (%)	Available P (ppm)	Available K (me $100g^{-1}$)	Organic C (%)	pH H_2O
A vs BCDEFGHI	0.70**	10.9**	1.09**	0.94**	6.84**
B vs CDEFGHI	0.68*	9.93*	0.91*	0.93*	6.85**
CDEF vs GHI	0.68*	9.28*	1.01**	1.00*	6.87*
CF vs DE	0.66*	1.00*	1.05*	1.10**	7.00**
C vs F	0.70**	9.60*	1.09^{ns}	1.20*	7.00^{ns}
D vs E	0.67*	8.50^{ns}	0.95^{ns}	0.90^{ns}	6.76^{ns}
GH vs I	0.63^{ns}	8.25*	$0.76n^{ns}$	0.85^{nn}	6.85*
G vs H	0.64*	8.90*	0.83*	0.80*	6.77^{ns}

Remarks: Based on Contrast orthogonal; ** = very significant; * = significant; ^{ns} = not significant

Table 4. N, P, K levels of plant tissues.

Treatment	N (%)	P (%)	K (%)
A vs BCDEFGHI	3.65**	0.33**	0.25**
B vs CDEFGHI	3.60*	0.32**	0.24*
CDEF vs GHI	3.58*	0.30**	0.24*
CF vs DE	3.58*	0.29*	0.23*
C vs F	3.65**	0.31**	0.25*
D vs E	3.48**	0.28 ^{ns}	0.21*
GH vs I	3.27**	0.23*	0.22*
G vs H	3.20^{ns}	0.24*	0.21*

Remarks: Based on Contrast orthogonal; ** = very significant; * = significant; ^{tn} = not significant.

as NPK combined with Trichoderma, compared to the control in parameters of total N, available P, available K, Organic C, and pH H_2O (Table 3). The same pattern is observed in the nutrient uptake parameters of plants (Table 4), indicated by P-values less than the significance level of 0.05. It suggests fertilizer application can enhance soil nutrient availability (Liu et al., 2009) and stimulate higher nutrient uptake (Kaya et al., 2020). The contrast orthogonal test results also show that the application of NPK fertilizer combined with Trichoderma significantly differs in terms of total N, available P, available K, organic C, and pH H_2O (Table 3), as well as N, P, K of plant tissues compared to the application of NPK fertilizer alone (Table 4). It indicates that adding Trichoderma can increase nutrient availability in the soil and nutrient uptake in plant tissues.

Trichoderma facilitates the availability of nutrients to plants through various processes, thereby improving soil properties and microbial activity, and maintaining soil fertility longer than chemical fertilizers. Trichoderma can be applied independently or with other chemicals and biofertilizers (Bhandari et al., 2021). The application of Trichoderma reduces the use of chemical NPK fertilizers, enhances micronutrient uptake, and aids in phosphate solubilization (Kamala, 2018). Trichoderma harzianum can improve nitrogen

Table 5. Plant height at 2, 4, 6, 8, and 10 weeks after planting (WAP).

Code	Plant height (cm)				
	2 WAP	4 WAP	6 WAP	8 WAP	10 WAP
A	31.6 ^{tn}	72.4 ^{tn}	132.2 ^{tn}	189.5 ^{tn}	198.9 ^{tn}
B	41.7**	96.7**	218.7**	250.6**	261.0**
C	41.9**	90.1**	213.7**	256.7**	261.1**
D	42.6**	93.8**	191.5*	245.2**	246.9**
E	46.5**	96.9**	222.1**	249.3**	258.5**
F	42.6**	95.8**	224.5**	260.8**	258.7**
G	40.0*	85.4*	213.6**	251.4**	243.0**
H	41.4**	91.9**	220.1**	247.4**	251.1**
I	42.1**	93.3**	212.1**	254.2**	243.6**

Remarks: ** = very significant; * = significant; ^{ns} = not significant

Table 6. Number of leaves at 2, 4, 6, 8, and 10 weeks after planting (WAP)

Code	Number of values				
	2 WAP	4 WAP	6 WAP	8 WAP	10 WAP
A	8.1 ^{tn}	7.9 ^{tn}	10.5 ^{tn}	11.2 ^{tn}	10.2 ^{tn}
B	9.5*	8.9*	11.6*	13.5**	10.6 ^{tn}
C	11.4**	9.5**	11.7*	13.4**	12.3**
D	12.2**	9.2**	12.3**	13.5**	13.2**
E	12.6**	9.9**	12.5**	13.5**	12.5**
F	13.2**	9.2**	12.4**	14.1**	13.2**
G	11.4**	9.4**	11.5*	12.3*	11.4*
H	11.6**	9.7**	11.2*	13.1**	11.5*
I	11.8**	8.9*	11.3*	12.5*	11.5*

Remarks: ** = very significant; * = significant; ^{ns} = not significant

Table 7. Stem diameter at 2, 4, 6, 8, and 10 weeks after planting (WAP).

Code	Stem diameter (cm)				
	2 WAP	4 WAP	6 WAP	8 WAP	10 WAP
A	0.18 ^{tn}	1.23 ^{tn}	1.95 ^{tn}	1.97 ^{tn}	2.90 ^{tn}
B	0.33**	1.56*	2.75**	3.23**	3.03*
C	0.22*	1.94**	2.73**	2.59*	3.27**
D	0.26**	1.84**	2.67**	2.73**	3.50**
E	0.33**	2.17**	2.81**	2.88**	3.16**
F	0.29**	2.10**	2.73**	2.62*	3.52**
G	0.23**	2.19**	2.42*	2.47*	3.26**
H	0.31**	1.81**	2.54**	2.59*	3.14**
I	0.24**	2.10**	2.55**	2.54*	3.54**

Remarks: ** = very significant; * = significant; ^{ns} = not significant

utilization efficiency in maize plants (Singh et al., 2018). These findings align with the research by Zin and Badaluddin (2020), indicating that Trichoderma-inoculated compost has higher compositions of N, P, and K compared to the control due to Trichoderma's ability to accelerate decomposition, thus increasing nutrient availability in the soil.

Contrast orthogonal test on Trichoderma application at 5 kg ha^{-1} with NPK fertilizer resulted in significant differences in total N, available P, available K, organic C, pH H_2O (Table 3), and also N, P, K of plant tissues (Table 4) when compared to Trichoderma treatments with lower rates. These results are in line with the research conducted by Sofyan et al. (2023), which showed that the combination of NPK fertilizer and Trichoderma at 2 kg ha^{-1} gave higher total N and C-organic content in the soil compared to lower Trichoderma doses. It is related to the role of Trichoderma in accelerating the decomposition of organic matter in the soil, thus affecting the availability of nutrients in the soil. Similarly, the same NPK dose treatment accompanied by different doses of Trichoderma (G, H, I) significantly affected the parameters of soil available P and P, K of plant tissues, especially in the comparison of treatments with lower doses of Trichoderma. Meanwhile, in the contrast orthogonal test of the same Trichoderma dose treatment (C, F, D, E), the different doses of inorganic fertilizer also had a significant effect on the parameters of total N, available P, and C-organic (Table 3), as well as N, P, K of plant tissues (Table 4). It shows that the addition of inorganic fertilizers in the application of Trichoderma also affects the availability of nutrients. It can be caused by the synergistic effect of Trichoderma, which can facilitate the availability of N, P, and K nutrients by adding inorganic fertilizers (Sani et al., 2020).

The application of NPK fertilizers combined with Trichoderma fertilizer significantly differs in height, number of leaves, and stem diameter at 2, 4, 6, 8, and 10 WAP. This shows that the use of trichoderma is still supported by the use of inorganic fertilizers (NPK). Other studies have shown that the use of biological fertilizers combined with inorganic fertilizers has an effect on corn crop yields (Jati Purwani and Nurjaya, 2020).

Based on the ANOVA test above, the data of the research results, namely plant height, leaves number, and stem diameter at 10 WAP, are significant at 0.05. Based on these results, it can be seen that the application of Trichoderma combined with NPK has a significant effect on plant height (F Count = 5.069 > 0.002), number of leaves (F Count = 37.025 > 0.000), and stem diameter (F Count = 76.557 > 0.000). It shows the role of Trichoderma in increasing nutrient uptake (Lyu and Huang, 2022), which is used for stem and leaf development. According to Nugroho (2015), plant growth is influenced by the availability of nutrients and sufficient water in the soil.

Based on Tables 5, 6, and 7, applying Trichoderma combined with NPK showed plant height (Figure 2), number of leaves, and stem diameter significantly different from the control. However, it was not significantly different compared to treatments with different doses. Based on the preliminary soil analysis results, the research area includes less fertile soil. According to BPS Boyolali (2022), the soil type in the research location is Inceptisol soil. Inceptisol includes immature soil where the profile development is weak, so using this soil for agriculture and non-agriculture depends

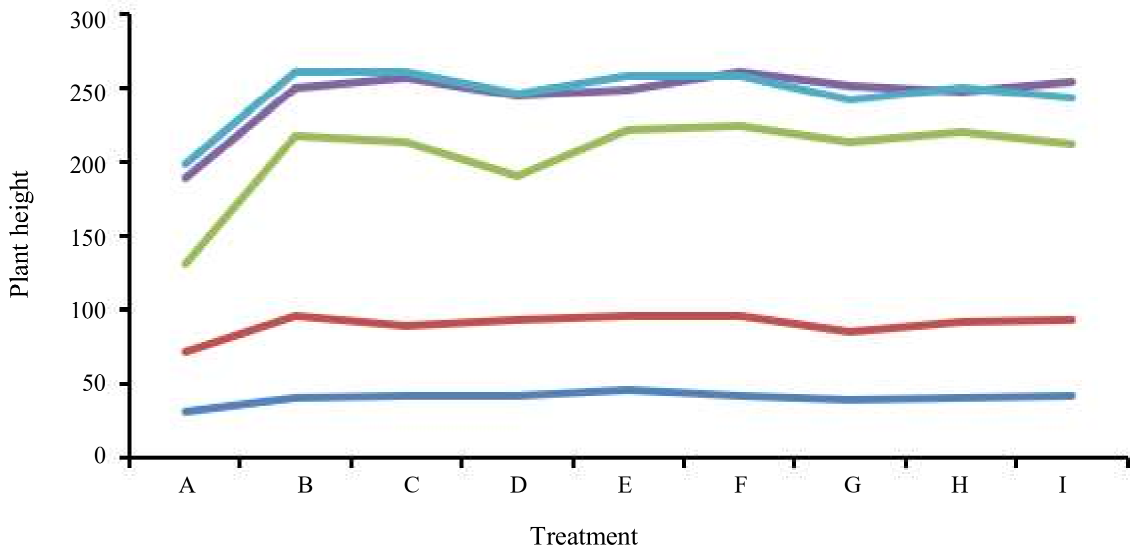

Figure 2. Plant height at 2, 4, 6, 8, and 10 weeks after planting (WAP). : 2 WAP, : 4WAP, : 6 WAP, : 8WAP, : 10 WAP.

on the environmental conditions where inceptisol is formed (Rajamuddin and Sanusi, 2014). The application of Trichoderma combined with NPK fertilizer can increase nutrients in the soil. Trichoderma can regulate pathogens through metabolic substances and decay of organic matter to increase soil fertility (Kusparwanti et al., 2022), increase nitrogen use efficiency and photosynthetic efficiency of plants, and indirectly play a role in improving soil structure indirectly (Amir and Dermawan, 2019).

Trichoderma treatment combined with NPK was able to increase total N, available P, and available K. However, the increase in soil nitrogen levels did not significantly increase compared to treating Trichoderma with different doses. According to Tyœkiewicz et al. (2022), Trichoderma has a role in increasing the solubility of nutrients contained in the rhizosphere, including phosphate, Fe^{3+}, Cu^{2+}, Mn^{4+}, ZnO, and can fulfill the necessary elements (nitrogen, phosphorus, potassium). Some of the studies explain that Trichoderma is able to encourage plant growth and development. This mechanism is explained by increased regulation of photosynthesis-related proteins, which results in better photosynthetic rates, plant nitrogen use efficiency, and increased plant nutrient uptake (Abdullah et al., 2021). In the Trichoderma treatment combined with NPK fertilizer with the highest dose, the available P results were low compared to the standard NPK treatment. The low available P is due to the lack of a Trichoderma dose and the condition of the research location, where the soil is sslightly acidic. The application of Trichoderma is, in fact, suitable for use in acidic soils because it can bind metals (Fe, Al, Mn) which is very useful when applied to acidic soils with the condition that P is bound to Al and Fe so that it becomes insoluble in the soil (Elita et al., 2021).

Applying Trichoderma affects NPK of plant tissues. According to Abdenaceur et al. (2022), Trichoderma can produce ammonia and nitrogen binding, which is critical in promoting growth. The increase in P of plant tissue follows the research of Promwee et al. (2014), who found an increase in phosphorus in cucumber shoots by 90% in soil, given *Trichoderma harzianum*. In addition, it also affects the plant height, number of leaves, and stem diameter. The results of research by Bedine et al. (2022) show corn plants given *Trichoderma virens* increase the rate of photosynthesis up to two times. According to research by Yahya et al. (2021), using *Trichoderma harzianum* T-22 on *Lantana camara* stimulates shoot elongation, thickening, and leaf development. In addition, nutrient levels in the soil and those absorbed by plants affect plant height, number of leaves, and stem diameter.

CONCLUSIONS

Trichoderma application combined with NPK fertilizer can increase the availability of soil N, P, and K. Application of Trichoderma 5 kg ha^{-1} with

NPK (Urea 350kg ha^{-1}, SP-36 200kg ha^{-1}, KCl 75 kg ha^{-1}) increased total N by 84.21%, available P 36.25% and available K, 142.22% against the control. The same treatment also increased corn plants' N, P, and K nutrients by 52.71%, 106%, and 61.53% against the control. Although the application of Trichoderma up to 5 kg ha^{-1} has not been able to reduce NPK fertilizer, its presence provides an opportunity to improve soil fertility.

ACKNOWLEDGMENTS

We want to thank the Dean of the Faculty of Agriculture. Sebelas Maret University provided the opportunity and use of the laboratory to carry out this research. Thanks are also expressed to PT Triagro Hijrah Jaya, which provided funding for this research.

REFERENCES

Abdenaceur R, B Farida, Tihar, D Mourad, H Rima, O Zahia and SH Fatma. 2022. Effective biofertilizer Trichoderma spp. isolates with enzymatic activity and metabolites enhancing plant growth. *Int Microbiol* 25: 817-829. doi: https://doi.org/10.1007/s10123-022-00263-8

Abdullah NS, F Doni, MS Mispan, MZ Saiman, YM Yusuf, MA Oke and NSM Suhaimi. 2021. Harnessing Trichoderma in agriculture for productivity and sustainability. *Agronomy* 11: 1-17. doi: https://doi.org/10.3390/agronomy11122559

Amir B and S Dermawan. 2019. Uji kombinasi trichoderma dan kompos terhadap pembentukan bintil akar dan produksi tanaman kacang tanah (Arachis hypogaea L.). *Savana Cendana* 4: 75-77. doi: https://doi.org/10.32938/sc.v4i04.834

Bedine MAB, B Iacomi, SN Tchameni, ML Sameza and FB Fekam. 2022. Harnessing the phosphate-solubilizing ability of Trichoderma strains to improve plant growth, phosphorus uptake, and photosynthetic pigment contents in common bean (Phaseolus vulgaris). *Biocatal Agr Biotech* 45: 102510. doi: https://doi.org/10.1016/j.bcab.2022.102510

Bhandari S, KR Pandey, YR Joshi and SK Lamichhane. 2021. An overview of the multifaceted role of Trichoderma spp. for sustainable agriculture. *Archives of Agriculture and Environmental Science* 6: 72-79.

BPS Boyolali. 2022. *Kecamatan Banyudono Dalam Angka 2022*. Boyolali.

Elita N, H Harmailis, R Erlinda and E Susila. 2021. Pengaruh aplikasi Trichoderma spp. Indigenous terhadap hasil padi varietas junjuang menggunakan system of rice intensification. *J Tanah dan Iklim* 45: 79-89. doi: https://doi.org/10.21082/jti.v45n1.2021.79-89.

Halifu S, X Deng, X Song and R Song. 2019. Effects of two Trichoderma strains on plant growth, rhizosphere soil nutrients, and fungal community of Pinus sylvestris var. mongolica annual seedlings. *Forests* 10: 1-17. doi: https://doi.org/10.3390/f10090758.

Hardjowigeno S. 2003. Ilmu Tanah. Jakarta: Akademika Pressindo pp.63-89

Isnaini S, A Niswati and Maryati. 2012. Screening of cultivable indigenous fungi which responsible for decomposing of rice straw. *J Trop Soils* 17: 61-66. doi: https://doi.org/10.5400/jts.2012.v17i1.61-66.

Kamala T and S Indira. 2011. Evaluation of indigenous Trichoderma isolates from Manipur as biocontrol agent against Pythium aphanidermatum on common beans. *Biotechnology* 1: 217-225. doi: https://doi.org/10.1007/s13205-011- 0027-3.

Kaya E, D Mailuhu, AM Kalay, A Talahaturuson and AT Hartanti. 2020. Pengaruh pupuk hayati dan pupuk NPK untuk meningkatkan pertumbuhan tanaman tomat (Solanum lycopersicum) yang di tanam pada tanah terinfeksi fusarium oxysporum. *Agrologia* 9: 360216.

Kusparwanti TR, HF Rohman, R Indriani, J Produksi, P Politeknik and N Jember. 2022. Respon pertumbuhan dan hasil tanaman jagung manis dengan pemberian pupuk organik yang diperkaya. *J Pertanian Cemara* 19: 1-18. doi: https://doi.org/10.24929/fp.v19i2.2242

Liu M, F Hu, X Chen, Q Huang, J Jiao, B Zhang and H Li. 2009. Organic amendments with reduced chemical fertilizer promote soil microbial development and nutrient availability in a subtropical paddy field: The influence of quantity, type and application time of organic amendments. *Appl Soil Ecol* 42: 166-175. doi:10.1016/j.apsoil.2009.03.006 10.1016/j.apsoil.2009.03.006

Oktasari W, P Laeshita, ED Novianto, N Anindyawati and A Lestiyani. 2021. Penyuluhan Pemanfaatan Trichoderma harzianum Lokal Sebagai Dekomposer dan Peningkatan Ketahanan Tanaman di Dusun Pendem, Kecamatan Ngablak. *Dedikasi: J Pengabdian kepada Masyarakat*, 1: 106-114. doi: https://doi.org/10.31479/dedikasi.v1i2.77.

Pandey P, V Irulappan, MV Bagavathiannan and M Senthil-Kumar. 2017. Impact of combined abiotic and biotic stresses on plant growth and avenues for crop improvement by exploiting physio-morphological traits. *Front Plant Sci* 8: 357. doi: https://doi.org/10.3389/fpls.2017.00537

Pratama RE, M Mardhiansyah and Y Oktorini. 2015. Waktu potensial aplikasi mikoriza dan Trichoderma spp. untuk meningkatkan pertumbuhan semai Acacia mangium. *Jom Faperta* 2: 1-11.

Promwee A, M Issarakraisila, W Intana, C Chamswarng and P Yenjit. 2014. Phosphate solubilization and growth promotion of rubber tree (Hevea brasiliensis Muell. Arg.) by trichoderma strains. *J Agr Sci* 6: 8-20. doi: https://doi.org/10.5539/jas.v6n9p8.

Purwani J and N Nurjaya. 2020. Effectiveness of inorganic fertilizer and biofertilizer application on maize yield and fertilizer use efficiency on inceptisol from West Java. *J Trop Soils* 25: 11-20. doi: https://doi.org/10.5400/jts.2020.v25i1.11-20.

Rajamuddin UA and I Sanusi. 2014. Morphological Characteristics and soil classification of inceptisol at some land systems in the Jeneponto District of South Sulawesi. *J Agroland* 21: 81-85.

Raza A, A Razzaq, SS Mehmood, X Zou, X Zhang, Y Lv and J Xu. 2019. Impact of climate change on crop adaptation and strategies to tackle its outcome: A review. *Plants* 8: 34. doi: https://doi.org/10.3390/plants8020034

Rodríguez LM, HAC Cornejo, SGA Garnica, ED Val and J Larsen. 2020. The interactions of Trichoderma at multiple trophic levels: inter-kingdom communication. *Microbiol Res* 240: 126552. doi: https://doi.org/10.1016/j.micres.2020.126552.

Sani MNH, M Hasan, J Uddain and S Subramaniam. 2020. Impact of application of Trichoderma and biochar on growth, productivity, and nutritional quality of tomato under reduced NPK fertilization. *Annals of Agricultural Sciences* 65: 107-115.

Singh BN, P Dwivedi, BK Sarma, GS Singh and HB Singh. 2018. Trichoderma asperellum T42 reprograms tobacco for enhanced nitrogen utilization efficiency and plant growth when fed with N nutrients. *Front Plant Sci* 9: 163. doi: https://doi.org/10.3389/fpls.2018.00163.

Singh SP, S Pandey, N Mishra, VP Giri, S Mahfooz, A Bhattacharya, M Kumari, P Chauhan, P Verma, CS Nautiyal and A Mishra. 2019. Supplementation of Trichoderma improves the alteration of nutrient allocation and transporter gene expression in rice under nutrient deficiencies. *Plant Physiol Biochem* 143: 351-363. doi: https://doi.org/10.1016/j.plaphy.2019.09.015

Sofyan ET, A Salsabilla and R Sudirja. 2023. The effect of trichoderma-enriched biofertilizer application on total nitrogen, organic carbon, and peanut (*Arachis hypogaea* L.) yield in Inceptisols. In *E3S Web of Conferences* 444: 04028 p. EDP Sciences.

Tyœkiewicz R, A Nowak, E Ozimek and J Jaroszuk-œcise³. 2022. Trichoderma: the current status of its application in agriculture for the biocontrol of fungal phytopathogens and stimulation of plant growth. *Int J Molecular Sci* 23. doi: https://doi.org/10.3390/ijms23042329.

Yahya AB, MD Al-Sawaf and NY Almura. 2021. Effect of biofertilizer trichoderma harzianum t-22 application, growing medium and training methods on some chararctrestics for lantana camara plants. *Mesopotamia J of Agriculture* 49: 97-105. doi: 10.33899/magrj.2021.127767.1059.

Zin NA and NA Badaluddin. 2020. Annals of agricultural sciences biological functions of trichoderma spp. for agriculture applications. *Ann Agr Sci* 65: 168-178. doi: https://doi.org/10.1016/j.aoas.2020.09.003