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Growth and Productivity of Four Cassava Cultivars on Several Levels of Mixed Fertilizers

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Abstract

Cassava is responsive to fertilization, and it is one of the important factors for high productivity. Root formation needs sufficient Phosphorus (P) and Potassium (K) nutrients, and adequate nutrients uptake increases root weight and starch content. However, the optimum effect of P and K fertilization should be balanced with Nitrogen (N) fertilization. The objective of the study was to determine the effect of mixed (inorganic and organic) fertilizers doses on the growth and yield of several cassava cultivars grown in Pati district, Central Java, Indonesia. The experiment was carried out during planting season in 2018. Four cassava cultivars (Litbang UK 2, UK 1 Agritan, Malang 4, and UJ 5) were tested under five doses of mixed fertilization. The split-plot design with three replicates was used in this experiment, where fertilizations as the main plot and cultivars as the subplot. The results showed that mixed fertilization had no significant effect, while the cultivars had a significant effect on growth and yield parameters as well as starch content. No significant interaction effect of the two factors, except in plant height.

Keywords: Environmentally-friendly fertilization, Improving cassava production, Optimal fertilizer, Prevent nutrient loss, Rational and balanced fertilization, Root yield, Soil fertility, Starch content

1. Introduction

Central Java Province contributes 15.70 % of the cassava (*Manihot esculenta* Crantz) production in Indonesia. Pati District, Central Java, Indonesia is one of the highest cassava producers among 12 other districts with a planting area of 20.000 ha and productivity of 43.55 t ha^{-1}. In this district, cassava is a commodity that attracts many farmers, and has become the main crop in their farming. So that, cassava production in Pati District in the period of 2011 to 2015 increased by 9.7 % each year (BPS Jawa Tengah, 2016). The appeal of cassava is triggered by the increasing demand for industrial raw materials.

The majority of cassava in Indonesia is grown on dry land with marginal soil fertility, and hence fertilization plays an important role in cassava cultivation. Several Inorganic Compound (Nitrogen, Phosphorus, and Potassium — NPK) fertilizers grades commonly used for food crops are 15-15-15, 20-10-10, and 30-6-8 (Budiono *et al*. 2019). Cassava plants are known to be very responsive to fertilization (Howeler, 2017). Increasing cassava productiveness due to NPK fertilization is well reported by Biratu *et al.* (2018). In the soil with low fertility, high rate of inorganic fertilizers are reqiured (Budiono *et al*., 2021; Macaloua *et al*., 2018). Agronomic research is needed to significantly increase the cassava yield through optimal fertilizer application (Ezui *et al*., 2016).

Cassava absorbs potassium (K) nutrients in high amount, even higher than N. For producing 30 t ha^{-1}, cassava uptake 147.6 kg N, 47.4 kg P_2O_5, and 179.4 kg K_2O. Potassium (K) has an important role in synthesis and accumulation of starch in cassava root (Fernandez *et al.*, 2017). However, imbalance fertilization hampered productivity and profitability (Hiironen and Riekkinen, 2016). Imbalance fertilization will also increase nutrient loss (Van der Velde *et al.*, 2014), and consequently degrade soil fertility (Adinurani *et al*. 2021, Li *et al.*, 2013), as well as pollute the environment (Muhammad *et al*., 2021; Utami *et al*. 2020). Cassava more response to inorganic fertilizer when combined with organic fertilizer (Biratu *et al.*, 2018). Badewa *et al*. (2020) recommend to use 100 kg N —22 kg P — 83 kg K ha^{-1} combined with 2.4 t ha^{-1} chicken manure to increase cassava yield. Optimum NPK fertilizer dosage varies among cultivar and environment. Wahyuningsih and Sutrisno (2019) found that to attain yield of 33 t ha^{-1}, Malang 4 cultivar grown under young teak stands needs fertilization of 125 kg Urea ha^{-1} + 150 kg SP36 ha^{-1} + 100 kg KCl ha^{-1}. Noerwijati and Budiono (2015) found different yield in different altitude with same fertilization at rates of 200 kg ha^{-1} Urea + 100 kg ha^{-1} SP36 + 100 kg ha^{-1} KCl, where the higher yield of

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54.84 t ha^{-1} attained at altitude of 80 m a.s.l., followed at 530 m a.s.l. (37.08 t ha^{-1}), and 7.79 t ha^{-1} at 800 m a.s.l.

The study was aimed to determine optimum dose of mixed (inorganic and organic) fertilizers on the growth and yield of several improved-cassava cultivars grown in Pati district, Central Java, Indonesia.

2. Materials and Methods

2.1. Experiment site

The field experiment was carried out during planting season of 2018 in Pati district, Central Java, Indonesia. Soil in the study site is acidic, but contains very low Al. The soil has very low organic matter, N, and Mg content, low Ca content, and medium available P, but high exchangeable K (Table 1).

Table 1. Soil properties in the experiment site.

Soil properties	Methods	Value	Criteria[1)]
pH-H_2O	1:5 (soil : H_2O)	4.68	L
C-organic (%)	Walkley & Black	1.21	VL
N-total (%)	Kjedahl	0.06	VL
P_2O_5 (mg kg^{-1})	Bray-1	13.6	M
Exchangeable K ($cmol^+ kg^{-1}$)	1 N NH_4OAc pH 7.07	0.24	H
Exchangeable Ca ($cmol^+ kg^{-1}$)	1 N NH_4OAc pH 7.07	1.08	L
Exchangeable Mg ($cmol^+ kg^{-1}$)	1 N NH_4OAc pH 7.07	0.05	VL
Exchangeable Al ($cmol^+ kg^{-1}$)	1 N KCl	3.39	VL

[1)]L=low, VL=very low, M=medium, H=high according to Howeler (2002; 2014), Howeler *et al*. (2019).

2.2. Treatment and experimental design

The experiment consisted of two factors which were laid out in a split-plot design, three replicates. The main plot was five fertilizer levels, namely P_1: 275 N + 45 P_2O_5 + 45 K_2O kg ha^{-1} (farmer practice as check), P_2: 135 N + 60 P_2O_5 + 30 K_2O kg ha^{-1}, P_3: P_2 + manure 0 t ha^{-1}, P_4: 130 N + 60 P_2O_5 + 60 K_2O kg ha^{-1}, and P_5: P_4 + manure 10 t ha^{-1}. The subplot was four cassava cultivars consisting of Litbang UK2 (V_1), UK1 Agritan (V_2), Malang 4 (V_3), and UJ5 (V_4). Urea 46 % N, SP36 36 % P_2O_5, and KCl 60 % K_2O use as the source of N, P, and K fertilizer, respectively.

2.3. Procedure

The soil was cultivated and mounded before planting. The cutting stems of 20 cm length were planted in plot measuring of 5 m × 5 m with planting distance of 1 m × 1 m. Phosphorus (P) and K fertilizer according to the treatments were applied once at 1 mo (month) after planting (MAP), while half dose of N fertilizer was applied at 1 MAP, and the remaining at 3 MAP.

2.4. Data collection and analysis

Growth variables (plant height and biomass), fresh root yields, yield components (number and weight of fresh root per plant, and harvest index), and starch content (wet base) were recorded at harvest (10 MAP). The plant height was measured from the stem above ground up to the tallest branch of the plant (Gyau 2015; Macalau *et al*. 2018). The shoot biomass measured based on weight of three plants at 9 mo after the crop was established (Pacheco *et al.* 2020. Yield components were observed from three plants (Fukuda *et al.* 2010). Yield was calculated through destructive harvesting by uprooting and weighing cassava roots from a 25 m^2 land area in the farmer's field, and the final yield (t ha^{-1}) calculated through extrapolation (Tarawali *et al*. 2012). Harvest index was calculated as the ratio of the storage root weight to the total biomass of shoots and storage root (Adjebeng-Danquah *et al.* 2016; Adu *et al.* 2020). Starch content was measured according to Fukuda *et al.* (2010). Red mite (*Tetranychus urticae* Koch) attacks was recorded during the growth according to Bellotti and Schoonhoven (1978). Observation of mite attack was carried out by scoring on the affected leaves, by giving a score 0 to healthy leaves (no spots), score 1 if there is early yellowish spotting (about 10 %) on some lower and/or middle leaves, score 2 if there is slightly yellowish spots (11 % to 20 %) on lower and middle leaves, score 3 if there is obvious damage; a lot of yellow spots (21 % to 50 %), few areas are necrotic (< 20 %), especially the lower and middle leaves are slightly wrinkled; some leaves turn yellow and fall off, score 4 if there is severe damage (51 % to 75 %) on the lower and middle leaves, the mite population is abundant and white threads are found like spider webs, and score 5 if total leaf loss occurs; plant shoots shrink; more and more white thread; plant death.

The collected-data were subjected to statistical analysis of variance (ANOVA) and the means were compared using the *LSD* test at a 5 % level of significance (Adinurani, 2016)

3. Result and Discussions

3.1. Soil chemical properties

The soil data indicate that soil fertility is low. The acidic soil pH with very low Al might be due to Ca and Mg cations leached-out from the top soil layer. Soil pH is classified as optimum for cassava growth because it is in the optimum soil pH range for cassava, which is 4.5 to 6.5, according to Howeler *et al.* (2019). The soil pH might not become a major limiting factor for cassava because it is still in the range of the optimum value.

Available P is medium, but it might become limiting factor because of low soil pH. Under low soil pH, P nutrient become less mobile due to Al or Fe fixation. Soil organic matter content as indicated by C-organic content is below the critical levels of organic matter of 3.2 % according to Howeler (2014), or at least at the critical level of 1.3 % according to Gomes (1998). Organic matter (OM) content is very low, and so that N content is also very low because OM is a main source of N in soil. The soil data indicate that soil fertility is low, and OM, N, P, Ca, and Mg might become the main constraint for cassava growth and high yield.

3.2. Growth and yield of four cassava cultivars

The results of the analysis of variance (ANOVA) showed that the fertilizer factor did not significantly affect all parameters observed, while the cultivars significantly affected all the parameters observed. There is no significant interaction between the two factors, except for plant height (Table 2). The genetic differences among cultivars have more effect on growth, yield, and yield components than fertilizer treatment.

Table 2. Results of ANOVA on all parameters observed.

Factor	Mean square value								
	Plant height (cm)	Shoot weight plant^{-1} (kg)	Biomass plant^{-1} (kg)	Number of root plant^{-1}	Root weight plant^{-1} (kg)	Root yield (t ha^{-1})	Harvest index	Starch content (% wb)	Starch yield (t ha^{-1})
Fertilizer (F)	0.08 ns	0.004 ns	0.02 ns	3.28 ns	0.10 ns	8.37 ns	0.004 ns	2.26 ns	0.28 ns
Cultivar (V)	0.11 *	0.035 **	0.10 **	5.70 *	3.29 **	5.81 **	0.049 **	26.10 **	5.13 **
F x V	0.06 *	0.002 ns	0.04	3.34 ns	0.05 ns	4.32 ns	0.003 ns	2.43 ns	0.19 ns
CV (%)	13.7	28.88	17.70	21.5	29.50	29.50	8.43	7.53	15.71

Annotation: ns = not significant, * = significantly different at 5 %, ** = significantly different at 1 %, wb = wet basis

Soil N, P, and organic matter in the experiment site were low, but application of N-P-K fertilizer, and also addition of organic fertilizer could not improve cassava growth (Table 3), as well as root yield and yield components (Table 4). The results indicate that fertilizer applied may be ineffective. Cassava in this experiment was planted in January 2018, so that the crop received high rainfall only for 3 mo (January to March), and rainfall decreased from April 2018 (Figure 1). It means that the plants suffer from drought after 3 MAP. The age at 3 MAP to 6 MAP is critical period for cassava because fast growing, root formation, as well as root development take place during that period. Lack of water will limit water absorption, as well as nutrient uptake which reduce crop growth and yield. Under these conditions, production efficiency was low as indicated by low harvest index. Plant height at harvest averaged 175.2 cm, biomass accumulation less than 1 kg plant^{-1} (Table 3), fresh root yield (14.22 to 16.29) t ha^{-1}, harvest index about 0.6, and starch content 13.82 % to 15.17 % (Table 4). Decrease in nutrient uptake occured in cassava plants under insufficient soil water (Howeler, 2012), and also reduction of plant height of cassava by 33 % to 47 % (Vitor *et al.*, 2019). Root yield, harvest index, and starch content in this experiment is low. In acidic soil in Lampung with fertilization of 135 N + 36 P_2O_5 + 30 to 60 K_2O kg ha^{-1}, UJ3 and UJ5 cultivar at 6 MAP produced (30 to 40) t ha^{-1} of fresh root with harvest index 0.7 to 0.8 and starch content >25 % (Taufiq *et al.*, 2015), and Malang 4 cultivar in East Java produced > 40 t ha^{-1} at 10 MAP with harvest index 0.7 to 0.8 and starch content > 26 % (Taufiq *et al.*, 2016).

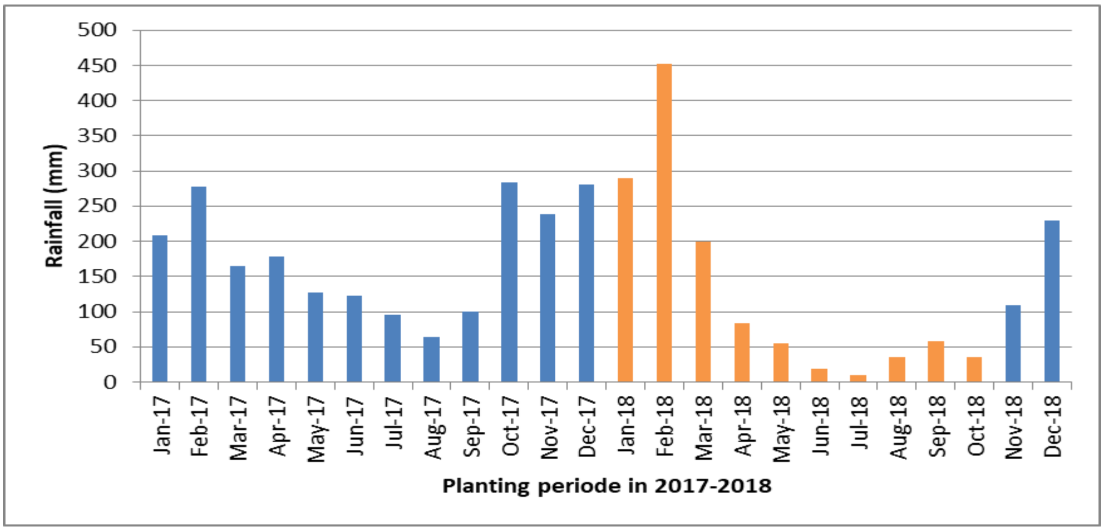

Figure 1. Rainfall in Pati District, Central Java, Indonesia during the experiment (January to October 2018).

Table 3. Effect of fertilizer doses on plant height, shoot weight, and biomass accumulation of cassava crop Pati district, Central Java, Indonesia 2018

Fertilizer doses	Plant height (cm)	Shoot weight plant^{-1} (kg)	Biomass weight plant^{-1} (kg)
P_1	185.8	0.24	0.99
P_2	165.8	0.21	0.89
P_3	168.6	0.22	0.89
P_4	180.0	0.20	0.91
P_5	175.9	0.25	0.95
Average	175.2	0.22	0.93
LSD (5 %)	0.19	0.05	0.196

Table 4. Effect of fertilizer on root number plant^{-1}, root weight plant^{-1}, root yield (t ha^{-1}), harvest index, starch content (% wb), and starch yield (t ha^{-1}), in dryland. Pati district, Central Java, Indonesia 2018

Fertilizer doses	Root number plant^{-1}	Root weight plant^{-1} (kg)	Root yield (t ha^{-1})	Harvest index	Starch content (% wb)	Starch yield (t ha^{-1})
P_1	7.11	1.59	14.32	0.61	14.32	2.44
P_2	8.11	1.59	14.22	0.64	13.82	2.29
P_3	7.44	1.68	15.15	0.65	14.62	2.48
P_4	7.99	1.64	14.76	0.63	14,69	2.46
P_5	8.33	1.81	16.29	0.65	15.17	2.72
Average	7.76	1.66	14.94	0.64	14.52	2.48
LSD (5 %)	0.93	0.252	2.27	0.025	1.08	0.44

The fertilization doses independently did not significantly affect the yield and the components of yield (Table 4). Similar to Pypers *et al.* (2011), the addition of fertilizer did not influence root yield. But reported by Cuvaca *et al.* (2017), fertilizer addition increased cassava root yield. Aplication 60 kg N ha^{-1} + 60 kg P_2O_5 ha^{-1} + 0 kg K_2O ha^{-1} increase root yield up to 27.7 t ha^{-1} compared with no fertilizer aplication. Organic matter utilization could improve root yield and soil fertility (Badewa *et al.* 2020), but in this study organic matter didn't improve the yield. Although not significantly different, it is seen that the root yield (t ha^{-1}) in the P_2 to P_5 fertilizer treatment is higher than the root yield in P_1 (farmer control) as well as the harvest index. Highest starch content and starch yield found in P_5 (130 kg N ha^{-1} + 60 kg P_2O_5 ha^{-1} + 60 kg K_2O ha^{-1} + manure 10 t.ha^{-1}) which indicate that increasing K fertilizer dose and the addition of manure could increase the starch content.

The effect of cultivars on plant height, shoot weight, and total plant weight (without root) were significantly different (Table 5). Plant height ranges from 164.3 cm to 182.9 cm. UK 1 Agritan grows tallest, while the shortest was Litbang UK 2 compared to the other cultivar. Growth parameters were more influenced by cultivar differences than fertilization treatment. According to Misganaw and Bayou (2020), variations in plant height can occur due to genetic variations. The highest shoot weight was achieved by the UK 1 Agritan variety while the lowest was the Litbang UK 2 cultivar. Likewise, the total plant biomass weight plant^{-1} (without root), the highest weight was achieved by UK 1 Agritan cultivar, and the lowest was UJ 5 cultivar. UJ 5 cultivar had a high shoot weight, but the stem was relatively small, so that the total plant biomass weight was the lowest among the other cultivars (Table 5). This indicates that UK 1 Agritan cultivar has better adaptability compared to the other cultivars.

Table 5. Effect of cultivars on plant height, shoot weight plant^{-1}, and biomass weight plant^{-1} in dryland. Pati District, Central Java, Indonesia 2018

Cultivars	Plant height (cm)	Shoot weight plant^{-1} (kg)	Biomass weight plant^{-1} (kg)
Litbang UK 2	164.3 b	0.17 b	0.88 bc
UK1 Agritan	182.9 a	0.27 a	1.01 a
Malang 4	173.1 ab	0.19 b	0.98 ab
UJ 5	180.6 a	0.26 a	0.84 c
Average	175.2	0.22	0.93
LSD (5 %)	0.13	0.05	0.12

Note : Mean values in each colum followed by different letters were significantly different ($P < 0.05$) .

The interaction between fertilizer doses and cultivar only significantly affected plant height. The highest plant height was achieved in the P_3V_2 treatment (195.0 cm), while the lowest was in the P_2V_1 treatment which was 140.7 cm (Figure 2). It can be seen that the UK 1 Agritan (V_2) variety which has good plant growth, plant height increased with the treatment P_3 (135 N + 60 P_2O_5 + 30 K_2O kg ha^{-1} + manure 10 t ha^{-1}). This indicates that the plant height of UK 1 Agritan didn't require the addition of K nutrients because the soil had high K nutrient, even the addition of K actually reduced plant height as shown in treatment P_4 and P_5.

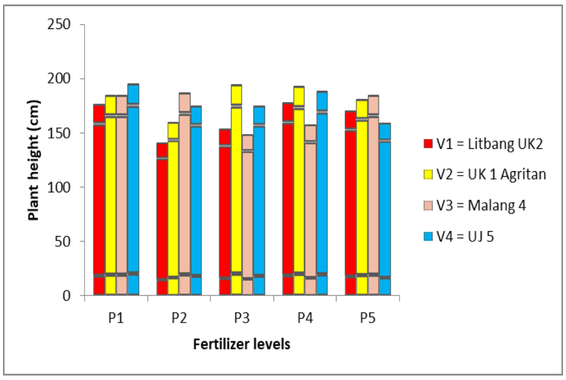

Figure 2. Effect of fertilization and cultivars on cassava plant height at 10 mo. Pati district, Central Java, Indonesia 2018. (P_1 = 275 N + 45 P_2O_5 + 45 K_2O, P_2 = 135 N + 60 P_2O_5+ 30 K_2O kg ha^{-1}, P_3 = P_2+ manure 10 t ha^{-1}, P_4 = 130 N + 60 P_2O_5+ 60 K_2O kg ha^{-1}, and P_5 = P_4 + manure 10 t ha^{-1}).

Cultivars showed significant differences in yield and yield components, namely the root number plant^{-1}, root weight plant^{-1}, root yield ha^{-1}, harvest index, starch content, and starch yield ha^{-1} (Table 6). These suggested that among varieties used, there were potential genetic differences.

The highest root number plant^{-1} was found in UJ 5 cultivar, but it was not significantly different with UK 1 Agritan cultivar. The smallest root number plant^{-1} was found in Malang 4. Likewise, the highest root weight plant^{-1} and the highest root yield ha^{-1} was in UK 1 Agritan cultivar, and the lowest was in the Litbang UK 2 cultivar. UK 1 Agritan was a cassava cultivar released in 2016 with early maturity characters. Based on farmers' information, UK 1 Agritan was quite preferred as a choice besides UJ 5 because it has not only high yield potential but also plant posture was not too large, with white root skin color. UK 1 Agritan also had a high harvest index (HI). HI is one indicator to estimate root yield. Harvest index were positively correlated (r = 0.61**) with root yield, so that the higher harvest index will have higher root yields. Karim *et al.* (2020) also found positive correlation between root yield and HI. The HI is variable to measure the efficiency of storage root production (Badewa *et al*., 2020). UJ 5 cultivar had the highest starch content followed by Malang 4 and Litbang UK 2, and the lowest was UK 1 Agritan (Table 6). Even though it has the lowest starch content, UK 1 Agritan has the highest root yield and hence the higher starch yield ha^{-1}.

Table 6. Effect of cultivar on root number, plant weight, root yield, harvest index, starch content, and starch yield in dryland. Pati district, Central Java, Indonesia 2018

Cultivars	Root number plant^{-1}	Root weight plant^{-1} (kg)	Root yield (t ha^{-1})	Harvest index	Starch content (% wb)	Starch yield (t ha^{-1})
Litbang UK 2	7.07 c	1.16 c	10.45 c	0.57 c	16.88 b	1.76 d
UK1 Agritan	8.11 ab	2.29 a	20.57 a	0.70 a	15.17 c	3.10 a
Malang 4	7.43 bc	1.53 b	13.77 b	0.61 b	16.52 b	2.29 c
UJ 5	8.41 a	1.67 b	14.99 b	0.67 a	18.38 a	2.76 b
Average	7.76	1.66	14.95	0.64	16.74	2.48
LSD (5 %)	0.97	0.18	1.66	0.036	0.95	0.29

Red mite pests commonly attack cassavas in the dry season. A red mite score, that was observed in the 3rd mo, was between 7.35 to 18.57. P_1V_3 treatment showed the lowest attack, and the highest in P_3V_3 treatment (Table 7). Fertilization treatment P_3 and P_5 had a higher mite attack score than the other treatments. It seems that the addition of organic matter can increase N nutrition, which causes plant tissue to become softer and it is easily attacked by mites. Altieri *et al* (2005) stated that an increase of N nutrient results in increased plant damage due to mites attack. Howeler *et al.* (2013) stated that application soil organic matter early in the cropping cycle, increases pest-regulating populations. To prevent more severe damage from mite attacks, spraying using Starban insecticides is carried out.

Table 7. Red mite pests population in cassava at 3 MAP.

Treatment	Mite score (%)				
	V1	V2	V3	V4	Average
P1	10.44	7.44	7.35	9.19	8.61
P2	12.57	8.36	12.03	6.93	9.97
P3	16.41	9.36	18.57	10.70	13.81
P4	11.50	11.55	11.48	9.69	11.05
P5	13.80	13.90	14.34	13.98	14.01
Average	12.94	10,12	12.75	9.50	

4. Conclusions

Reducing N fertilizer dosage from 275 kg N ha^{-1} to (130 to 135) kg N ha^{-1} and K from 45 K_2O ha^{-1} to 30 kg K_2O ha^{-1}, increasing P dosage from 45 P_2O_5 ha^{-1} to 60 P_2O_5 ha^{-1}, and application of 10 t ha^{-1} manure has no effect on both cassava growth and yield. Agronomic and yield performance of UK 1 Agritan cultivar is better than Litbang UK 2, Malang 4, and UJ 5 cultivars, and hence can be recommended as an alternative cultivar for farmers in the Pati area, Central Java, Indonesia. But the increase in N nutrient increases the attack of mite pests.

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