

Growth and Yield of Corn (*Zea mays* L.) With Application Ammonium Chloride Fertilizer

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Abstract

The high yield gap between the potential of varieties and the real production of corn in the field is one of the problems in meeting the national corn needs, so various efforts to increase productivity are continuously carried out, one of which is the application of inorganic fertilizers that are suitable for plant needs and specific. The study was conducted at KP Mojosari AIAT East Java from November 2020 to February 2021. The experiment used a randomized block design (RAK) with 5 replications and 6 treatments including control (without fertilizer) and 5 other treatments which were a combination of the dose of ammonium chloride fertilizer and the dose of urea fertilizer. The results showed that treatment F showed the highest yields on plant height and canopy width, treatment E showed best results on leaf width variables, and treatment C showed the highest results on stem diameter variables. Meanwhile, result parameter shows that all treatment combinations obtained higher results than the control. The conclusion is that this ammonium chloride fertilizer can be used for corn because it has an additional Cl element which is useful for the efficient use of nitrogen in plants, but the application of Cl must be limited.

Keyword: corn, fertilizer, yield

Introduction

In East Java, in 2016, the corn harvested area reached 1,238,616 ha with production reaching 6.2 million tons, which means that corn productivity was 5.07 t/ha (BPS, 2017). Meanwhile, the production potential of New Superior Varieties (VUB) of maize can reach 8–10 t/ha (Balitsereal, 2018). This relatively large difference in production means that there are still opportunities for efforts to increase productivity in maize development. This is due to several environmental factors, including climate and soil conditions, considering that plants require optimal conditions to be able to produce high yields. To be able to grow and produce optimally, corn plants need sufficient nutrients during their growth. The balance of nutrients (N, P, and K) is an essential macro nutrient for the growth and yield of maize (Tabri, 2010).

The BPS (2018) stated that Indonesia's total corn imports in 2018 reached 737,220 tons. The lack of domestic production capacity to meet demand is due to corn productivity, which is far below its potential productivity. According to Zubachtirodin et al. (2011), productivity at the farm level is still highly variable between 1 and 7 t/ha. Several agencies, both government and private, conducting research and development of corn have provided corn with a potential yield of up to 13 tons per hectare.

The use of inorganic fertilizers continuously and in high doses will damage plants and the environment (Lestari, 2009). In addition to increasing production costs, the continuous use of inorganic fertilizers can damage the environment by emitting N₂O and making the soil dense and not porous. Not all inorganic fertilizers that are given can be absorbed by corn plants. The

availability of nitrogen nutrients is one of the most common problems in cultivated soils (Fahmi et al., 2010). In addition, the nitrogen content in the soil is very mobile, depending on the nature of the soil, the type of plant, and the phase of plant growth (Havlin et al., 2005).

Nitrogen requirements in different plants vary. Corn plants need about 3% nitrogen to support their growth. In the meantime, the nitrogen content of mineral soils is typically less than 3% (Buckman & Brady, 1982; Sonbai et al., 2013). Therefore, N fertilization is a must to get optimal productivity. Ammonium Chloride (NH₄Cl) is one type of nitrogen fertilizer. This fertilizer contains 26% N and 0.07% Cl. This fertilizer has a white physical characteristic with a shape resembling a crystal (National Standardization Agency, 2005). Ammonium Chloride (NH₄Cl) fertilizer has the advantage of having a high level of nutrient utilization (Chai et al., 2017). This research was conducted to determine the effectiveness of ammonium chloride fertilizer on the growth and yield of maize.

Materials and Methods

The research was conducted at KP Mojosari Kab. Mojokerto, in geographical conditions between 7°55'54.31" latitude and 112°34'01.69" east longitude, at an altitude of 100 meters above sea level (masl) in November 2020–February. The research material in this study consisted of BISI-18 hybrid corn seeds, Urea fertilizer, NPK and ammonium chloride fertilizer.

The research design was a randomized block design with 5 (five) replications, consisting of 6 (six) treatments including control (without fertilizer) and 5 other treatments which were a combination of the dose of ammonium chloride fertilizer and the dose of urea fertilizer, and NPK. Each experimental plot is 7 x 5 m (Table 1).

Table 1. Fertilization treatment of ammonium chloride, urea, and NPK.

Code	Fertilizer Dosage (kg ha ⁻¹)			
	Organic (t.ha ⁻¹)	Urea	NPK Phonska	Ammonium Chlorida
A	0	0	0	0
B	2	250	300	0
C	2	187.5	300	111
D	2	125	300	221
E	2	62.5	300	332
F	2	0	300	442

Planting corn using tugal with a spacing of 70 cm x 20 cm and 1-2 seeds per planting hole. N fertilization (urea and ammonium chloride) was applied as much as one-third of the dose at 7 HST, one-third of the dose at 28 HST, and one-third of the dose at 35 HST. Phonska NPK fertilizer was applied at 50% of the dose at 7 HST and 50% at 28 HST, and organic fertilizer was applied at the time of planting to cover the planting hole. Control of pests with insecticides in accordance with the recommended dose. Irrigation is carried out every 2-3 weeks according to the conditions in the field. The variables observed were: plant height, number of leaves, stem

diameter, leaf area ratio, wet weight of cobs, number of cobs per plant, and production per converted plot per unit area (hectare).

Result

A. Soil analysis

Soil analysis was carried out before the test took place. Soil analysis was carried out at each block location and then composited. Soil analysis prior to testing was carried out to obtain information on nutrient status that would be used to support recommended fertilizer data and suitability with the tested NPK fertilizers. The results of the soil analysis carried out are shown in Table 2. Based on the results of the analysis, it shows that the N content at the test site is classified as low to very low. This makes the research location suitable to be used for effectiveness test locations. The K content in the soil also has a low to moderate value, so the addition of K elements in the soil is very necessary. The P content in the soil is very high, but P in the soil is very easily absorbed into the soil. Soil pH in the research area was at a value of 7.3 where the pH requirement of corn on S1 class land was 5.5-7.0. Land with a pH of 7.3 is classified as a corn field with class S2 where improvements and additional inputs are needed.

Table 2. Results of soil analysis at the research site

Parameter	Unit	Value	Description
pH	-	7,3	Neutral
C Organic	%	0.38	Very Low
N	%	0,03	Very Low
P	ppm	38	Very High
K	Cmol(+)/kg	0.65	Low-Medium

Description: analyzed in the East Java AIAT soil lab

B. Height of the plant

Plant height showed significant differences between treatments, according to table 3.

Table 3. Effect of various fertilizer dosage treatments on corn plant height

Treatment	Plant Height (cm)					
	18 HST	29 HST	43 HST	58 HST	72 HST	87 HST
A	30,16	47,20 a	79,4 a	110,9 a	127,0 a	126,4 a
B	33,84	63,96 b	139,6 b	181,1 b	185,3 b	187,4 b
C	34,92	64,44 b	139,1 b	183,6 b	185,9 b	187,9 b
D	33,04	63,12 b	135,6 b	188,3 b	186,0 b	186,9 b
E	34,40	62,32 b	130,5 b	180,4 b	182,2 b	179,6 b
F	35,84	65,00 b	142,0 b	191,2 b	194,0 b	194,1 c
BNT 5%	tn	7,17	16,59	14,42	15,12	14,33

The application of urea and ammonium chloride fertilizers affected the height of corn plants during the vegetative phase compared to without urea and ammonium chloride fertilizers. The height of corn plants continues to increase along with the addition of plant age. From 29 HST to 87 HST, all fertilizing treatments showed higher plant heights than those without fertilization. The height of corn plants in the vegetative phase at 87 HST due to ammonium chloride fertilization ranged from 179.6 to 194.1 cm, while the height of maize plants without ammonium chloride fertilization was 126.4 cm. The highest yield was found in treatment F. This indicated that urea and ammonium chloride fertilization were able to increase the height of corn plants during the vegetative phase 42–53% higher than without urea and ammonium chloride fertilization. These results are in accordance with the research of Chen et al. (2020) that showed that the administration of ammonium was able to increase the height of corn plants compared to without giving ammonium, and were strengthened by the results of the research of Sofyan et al. (2017) that showed that the application of "BUMI IJO" Ammonium Chloride with a dose of the recommended dose was able to increase plant height compared to other treatments.

C. Count of Leaves

The results of observations on the number of leaves also stated different results between treatments according to table 4.

Table 4. The effect of various fertilizer dosage treatments on the number of leaves of corn plants

Treatment	The number of leaves (strands))			
	18 HST	29 HST	43 HST	58 HST
A	4,20	4,12 a	6,16 a	12,92 a
B	4,52	5,28 b	8,40 b	13,92 b
C	4,68	5,40 c	8,20 b	14,28 b
D	4,48	5,08 b	8,20 b	14,08 b
E	4,56	4,96 b	7,76 b	13,84 b
F	4,44	5,28 b	8,08 b	14,32 b
BNT 5%	tn	0,41	0,88	0,68

The number of leaves of corn plants continues to increase along with the age of the plant. All fertilizing treatments showed a higher number of leaves than without fertilization, from 29 HST to 58 HST. The number of leaves of maize plants at the age of 58 HST due to ammonium chloride fertilization ranged from 13.84 to 14.32 leaves, while the number of leaves of maize plants without ammonium chloride fertilization was 12.92 leaves. This shows that ZA and Ammonium Chloride fertilization can increase the number of leaves of corn plants by 7–11% more than without Ammonium Chloride fertilization. These results are in accordance with the research of Paul et al. (2019). The application of fertilizer containing N was able to produce a greater number of leaves, especially at harvest time. According to Su et al. (2020), the application of fertilizers containing the element N in optimum amounts can increase plant growth and yield as well as increase the efficiency of the use of solar radiation and nitrogen use. The taller the corn plant, the greater the number of segments so that it can increase the number of plant leaves (Amin, 2011).

D. Rod length

The results of the analysis of variance showed significant differences in stem diameter due to different doses of ammonium chloride fertilizer. The difference in stem diameter was found in all ages of observation (Table 5).

Table 5. shows the effect of different ammonium chloride fertilizer doses on the stem diameter of corn plants.

Treatment	stem diameter (mm)				
	29 HST	43 HST	58 HST	72 HST	87 HST
A	11,30 a	22,05 a	16,86 a	15,18 a	16,20 a
B	17,08 b	28,19 b	22,15 b	23,49 b	22,48 b
C	17,55 c	28,28 b	22,57 b	23,15 b	22,57 b
D	15,47 b	29,02 b	21,92 b	21,36 b	21,68 b
E	15,56 b	28,70 b	22,41 b	22,44 b	22,61 b
F	16,66 b	28,55 b	22,34 b	22,88 b	22,57 b
BNT 5%	2,08	1,94	1,34	2,23	1,58

The application of ammonium chloride fertilizer affected the stem diameter of corn plants compared to without the application of ammonium chloride fertilizer. The stem diameter of corn plants continues to increase with the age of the plant. All fertilizing treatments showed larger stem diameters compared to treatments without fertilization, starting from 29 HST to 87 HST. The stem diameter of corn plants at 58 HST due to ammonium chloride fertilization ranged from 21.68 to 22.61 cm, while the stem diameter of maize plants without ammonium chloride fertilization was 16.20 cm. These results indicated that Ammonium Chloride fertilization was able to increase the stem diameter of corn plants by 34–39% greater than without Ammonium Chloride fertilization. These results are in accordance with Amin's research (2011). Application of fertilizers containing N can increase the diameter of corn stalks due to the availability of N, which can increase plant growth.

E. Leaf size

The results of the analysis of variance showed significant differences in leaf length due to different doses of ammonium chloride fertilizer. Differences in leaf length were found in all ages of observation (Table 6).

Table 6. Shows the effect of different ammonium chloride doses on the leaf length of maize plants.

Treatment	Leaf length (cm)		
	58 HST	72 HST	87 HST
A	72,64 a	71,44 a	66,46 a
B	92,14 b	87,30 b	85,00 b
C	90,04 b	82,99 b	81,00 b
D	89,52 b	83,10 b	80,16 b
E	92,70 b	86,26 b	85,34 b
F	92,12 b	86,12 b	85,68 b
BNT 5%	4,52	4,44	5,63

All fertilizing treatments showed longer leaf lengths compared to treatments without fertilization, ranging from 58 HST to 87 HST. The leaf length of maize plants at 87 HST due to ammonium chloride fertilization ranged from 80.16 to 85.68 cm, while the leaf length of maize plants without ammonium chloride fertilization was 66.46 cm. These results showed that ZA and Ammonium Chloride fertilization were able to increase the leaf length of maize plants by 20–29% longer than without Ammonium Chloride fertilization. The use of fertilizers containing Cl elements can benefit corn plants to avoid leaf wilting, chlorosis, and necrosis due to Cl deficiency (White & Broadley, 2001). The length of the leaves of corn plants at the age of 87 DAP ranged from 80.16 to 85.86 cm. These results indicate that the treatment of various doses of ammonium chloride fertilizer gave the same response to the leaf length of corn plants as ZA or urea fertilizer, so that ammonium chloride fertilizer can be used as a substitute for ZA or urea fertilizer. This is supported by the research of Xu et al. (1999), where the application of fertilizer containing chlorine at a dose of 400 kg ha⁻¹ can increase the yield of corn seeds. In addition, the element Cl can increase the efficiency of nitrogen use so that the accumulation of biomass by plants becomes higher (Rosales et al., 2020).

F. Leaf Diameter

The results of the analysis of variance showed a significant difference in leaf width due to the dose of ammonium chloride fertilizer. Differences in leaf width were found at 58 HST, while at 72 and 87 HST were not significantly different (Table 7).

Table 7. Effect of various doses of ammonium chloride fertilizer treatment on leaf width of corn plants

Treatment	Leaf Width (cm)		
	58 HST	72 HST	87 HST
A	6,48 a	6,76	6,29
B	8,61 b	7,99	6,92
C	8,30 b	7,52	6,44
D	8,30 b	8,74	5,98
E	8,72 c	7,99	6,97
F	8,51 b	7,79	6,70
BNT 5%	0,38		

The leaf width of corn plants tends to decrease with the increase in plant age. All fertilizing treatments showed higher leaf width compared to no fertilization, especially at 58 DAP, then leaf width became narrower at 72 and 87 DAP. The leaf width of maize plants at the age of 58 DAP due to Ammonium Chloride fertilization ranged from 8.30–8.72 cm, while the leaf width of maize plants without ZA and Ammonium Chloride fertilization was 6.48 cm. The highest leaf width treatment at 58 DAP was found in treatment E. These results showed that ammonium chloride fertilization was able to increase the leaf width of maize plants by 28–34% higher than the treatment without fertilization. The increase in leaf width only occurs until the final vegetative phase, where when entering the generative phase there is a decrease in leaf width. This is presumably because the absorption of N elements from ammonium chloride fertilizer occurs only during the vegetative phase. According to Malagoli et al. (2005), most of the N will

be absorbed during the vegetative phase and only a small portion of N will be absorbed after flowering.

According to Xu et al. (1999), corn plants are classified as less sensitive to the application of chlorine fertilizer so that the generative growth does not show differences in leaf width. However, too much Cl accumulation in the soil can cause the process of leaf dilation to be hampered, thereby reducing leaf area (Blanco et al., 2008).

G. Variable generative

The results of the analysis of variance showed significant differences in several characteristics of cobs and seeds (Table 9). The characteristics of the cobs and seeds that were affected by the treatment of several doses of fertilization were the weight of the cobs, the length of the ears, the diameter of the ears, the weight of the shells and the moisture content, while the weight of 100 seeds was not affected by the treatment.

Table 9. Effect of various doses of ammonium chloride treatment on cob weight, cob length, cob diameter, shell weight, moisture content, and weight of 100 corn seeds.

Treatment	Cob Weight (g)	Cob Length (cm)	Cob Diameter (cm)			Pipil Weight (g)	Moisture (%)	Content 100 grams of seeds (g)
			Top	Middle	Bottom			
A	43,4 a	6,5 a	34,0 a	33,5 a	28,6 a	154,5 a	36,7 b	30,2
B	218,4 b	16,5 b	46,7 b	45,0 b	37,9 b	866,6 b	32,8 a	33,0
C	213,1 b	15,9 b	46,2 b	45,1 b	38,0 b	838,0 b	33,0 a	34,0
D	192,7 b	15,0 b	44,7 b	43,3 b	37,7 b	752,6 b	32,5 a	34,6
E	193,2 b	15,5 b	44,5 b	43,8 b	37,7 b	749,0 b	32,8 a	32,6
F	210,0 b	16,1 b	45,2 b	44,3 b	37,6 b	846,2 b	31,8 a	34,0
BNT 5%	43,6	1,81	3,43	2,57	2,96	182,2	1,59	tn

The different doses of ammonium chloride fertilizer showed differences in the weight of the cobs. The application of ammonium chloride fertilizer with different doses showed a significant increase in cob weight compared to without ammonium chloride fertilization. The weight of the cobs in the ammonium chloride fertilizing treatment ranged from 192.7–218.4 g per ear, while the treatment without ammonium chloride fertilization was 43.4 g. These results showed that the application of ammonium chloride fertilizer was able to increase the weight of the cobs by up to

4 times more than without fertilization. The availability of N elements from ammonium chloride fertilizer in sufficient quantities can increase the resistance of corn plants to stress and be more effective in producing biomass and corn cob production. Increasing the dose of nitrogen up to a dose of 15 g N m⁻² was also able to increase the yield of corn cobs (Di Paolo & Rinaldi, 2008).

The length of the ear and the diameter of the ear were affected by different doses of ammonium chloride fertilizer. The application of ammonium chloride fertilizer with different doses showed an increase in the length of the ear and the diameter of the ear, both the upper, middle, and lower ear diameters. The length of the cob due to the treatment with ammonium chloride fertilizer doses reached 15.0–16.5 cm, or 1.5 times higher than without ammonium chloride fertilization, which only reached 6.5 cm. In addition, the diameter of the upper, middle, and lower ears due to ammonium chloride fertilization was also higher than without ammonium chloride fertilization. These results are in accordance with the research of Haghighat et al. (2011), where increasing the dose of N fertilizer was able to increase the diameter of the corn cobs.

Treatment with ammonium chloride fertilizer and treatment without fertilization showed a significant difference. The application of ammonium chloride fertilizer with different doses was able to increase the weight of corn shells compared to without the application of ammonium chloride fertilizer. The weight of shelled corn due to the application of different ammonium fertilizers ranged from 749.0–866.6 g, while the weight of shelled corn without the application of ammonium chloride fertilizer was 154.5 g. These results showed that the application of ammonium chloride fertilizer was able to increase the weight of corn shells up to 4.5 times higher than without ammonium chloride fertilization. These results are in accordance with the research of Shapiro & Wortmann (2006), which found that the addition of N elements can increase the yield of corn seeds up to 22% higher than without fertilization. In addition, ammonium chloride fertilizer also contains Cl elements, which have various functions, especially in maintaining osmoregulation of plant cells (Franco-Navarro et al., 2016). The element Cl can also suppress disease attacks that attack corn plants (Lamond et al., 2000).

The treatment of different doses of ammonium chloride fertilizer also affects the water content. The water content due to treatment with ammonium chloride fertilizer was lower than the water content without ammonium chloride fertilization. The water content without fertilization was 36.7%, while the water content due to the application of ammonium chloride fertilizer ranged from 31.8 to 33.0%. These results also indicate that the application of ammonium chloride fertilizer in various doses did not cause differences in water content.

Conclusion

Fertilizer dosage 0 kg ha⁻¹, 442 kg ha⁻¹ Ammonium Chloride and 2000 kg ha⁻¹ organic, 300 kg ha⁻¹ NPK Phonska, 0 kg ha⁻¹, 442 kg ha⁻¹ Ammonium Chloride produced dry shelled corn that outperformed the standard treatment. This ammonium chloride fertilizer can be used for corn because it has an additional Cl element, which is useful for the efficient use of nitrogen in plants, but the application of Cl must be limited because it will cause the soil to become saline.

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