

Determination of the Optimum Rates for N, P, and K Fertilizer for Upland Rice Variety “IPB 9G”

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Abstract

A study was conducted to determine the optimum rates of N, P, K fertilizers on “IPB 9G” upland rice variety from March to July 2018 at the Sawah Baru Experimental Field of IPB University, West Java, Indonesia. Three parallel experiments were carried out in a randomized complete block design to test five fertilizing levels, i.e. 0, 50, 100, 150 and 200% of the reference rate. The reference rates of fertilizer application are 100% N = 200 kg Urea ha⁻¹, 100% P = 100 kg SP36 ha⁻¹, and 100% K = 100 kg KCl ha⁻¹. The applied fertilizers were Urea (46% N), SP36 (36% P₂O₅) and KCl (60% K₂O). Fertilizers were applied three times, 40% at planting, 30% at 4 WAP and the rest 30% at 8 WAP; 100% P and 100% K were applied at planting. Increasing N fertilizer from 0 to 200% of the reference rate increased plant height, dry weight biomass at heading and at harvest, number of productive tillers, harvest index, and grain weight per clump. P increased dry weight of the above ground biomass, whereas K fertilizer increased the leaf area, canopy dry weight, number of grain per panicle, panicle length, harvest index and grain weight per clump. The optimum rate of N and P were 107.09 kg Urea ha⁻¹ and 63.3 kg P₂O₅ kg.ha⁻¹, respectively, whereas the optimal rate for K fertilizer for “IPB 9G” could not be determined with this study.

Keywords: *Oryza sativa*, grain weight, growth phase, harvest index, plant growth rate

Introduction

Rice (*Oryza sativa* L.) plays an important role in the food supply in Asia, including Indonesia. Approximately 95% of the Indonesian population consumes rice as a staple food (Syakhril et al., 2014). Norsalis (2011) reported that consumption of rice can cover 63% of the total energy adequacy and 37% of protein. Efforts to increase rice production in Indonesia is still focused on intensification of culture as massive

conversion of agricultural land into non-agriculture has significantly decreased the rice production area (Ministry of Agriculture, 2004).

Around 5.1 million ha of dry land spread across various provinces in Indonesia has potential to be used to grow upland rice (Toha, 2007; Hidayat, 2011). The current data from BPS in 2014, however, showed that the potential area has drop into 3,292,578 ha. The common problems of developing dry land area is caused by low levels of soil fertility. The use of new rice varieties which are resistant to pests and diseases, and management of efficient application of fertilizer can potentially increase rice productivity in the dry land area.

IPB University has released new superior varieties of upland rice, named “IPB 8G” and “IPB 9G”. “IPB 9G” variety has a potential yield of 9.09 tons.ha⁻¹ with an average yield of 6.09 ton.ha⁻¹. Both varieties have resistance to several races of blast disease infection (Food Crop Research and Development, 2017). Superior varieties in general require balanced nutrients, especially N, P and K, to reach their potential high yields. The availability of N, P and K on soil is the most limiting factor to rice growth and yield (Munawar, 2011). Putra (2012) reported that fertilizing with 200 kg NPK, 50 kg urea, and 201 kg per ha could increase the yield of upland rice “Situ Patenggang” to 3.4 t.ha⁻¹, or 58% higher compared to the application of 200 kg urea single fertilizer, 100 kg of SP 36 and 50 kg.ha⁻¹ of KCl per ha. According to Ramadhan (2014) application of NPK fertilizer can significantly improve rice growth. In addition, Krismawati and Firmansyah (2014) also stated that the use of fertilizers N, P, K could increase plant height, number of tillers, panicle, grain weight, and yield of “Situ Patenggang” variety. Most rice growers tend to use the excessive amount of fertilizer to increase yield. The objective of this study is to determine the optimum doses of N, P, and K fertilizers for upland rice “IPB 9G”.

Material and Methods

Time and Place

This study was carried out at the Sawah Baru Experimental Station of Department of Agronomy and Horticulture, IPB University from March to July 2018. "IPB 9G" seeds were used for this study.

Experimental Design

The experiment consisted of three parallel experiments, each to determine the optimum fertilization of N, P, and K (Table 1). Each trial tested five levels of fertilizer doses, i.e., 0, 50, 100, 150 and 200% of the reference rate, which are 100% N = 200 kg Urea; 100% P = 100 kg SP36; and 100% K = 100 kg KCl per ha (Doberman and Fairhurst, 2000). The three experiments consisted of a total of 45 plots organized in a completely randomized block design; each treatment was replicated three times.

Fertilizer Application

The fertilizers used in this study were Urea (46% N), SP36 (36% P₂O₅), KCl (60% K₂O). The N fertilizer was applied at three stages, 40% at planting, 30% at 4 week after planting (WAP), and the rest of 30% at 8 week after planting. Both P and K fertilizers were applied 100% at planting.

Measurement and Observation

The physical and chemical properties of the soil were analysed prior to and after the experiment. Growth

parameters measured are height (cm), number of tillers, leaf area (cm²), canopy dry weight (g), yield and yield components, namely the number of productive tillers, number of grains per panicle, harvest index and grain weight per clump (g).

Determination of Optimum Fertilizer Dose

The optimum N, P, and K fertilizer doses were determined by calculating the relative yield, which was the value of a variable compared to the maximum value of the variable obtained from each dose, using the following formula of Suminar (2016) :

$$Y_i/Y_{max} \times 100\%$$

where

Y_i = the values of the treatment variables N, P, and K- i^{th}

Y_{max} = maximum values of the nutrients N, P, K variables

The determination of the recommended options was conducted at the end of the study using a multi-nutrient response approach based on the grain weight per clump variable (Jannah, 2012; Rohmawati, 2013). This approach was used to determine fertilizer recommendations using the quadratic model of several fertilization experiments. The relative results were converted into quadratic equations, then used to determine the selection of recommendations. The maximum fertilizer dose was determined using the quadratic regression model $y = ax^2 + bx + c$ with y = relative plant values, x = fertilizer dosage, whereas a , b , c are constant values. The determination of the

Table 1. Fertilizer doses of the experiment with N, P, and K fertilizer

Fertilizer	% Reference doses				
	0	50	100	150	200
N fertilizer experiment (kg.ha ⁻¹)					
N	0	46	92	138	184
P ₂ O ₅	36	36	36	36	36
K ₂ O	60	60	60	60	60
P ₂ O ₅ fertilizer experiment (kg.ha ⁻¹)					
N	92	92	92	92	92
P ₂ O ₅	0	18	36	54	72
K ₂ O	60	60	60	60	60
K ₂ O fertilizer experiment (kg.ha ⁻¹)					
N	92	92	92	92	92
P ₂ O ₅	36	36	36	36	36
K ₂ O	0	30	60	90	120

maximum fertilizer dosage was calculated by using the derivative formula of the regression equation: $dy/dx = 2a + xb = -b/2a$ (Suminar, 2016).

Results and Discussion

General Condition

Based on information from the Meteorology, Climatology and Geophysics Agency (BMKG) Dramaga Climatology Station, Bogor (2018) Sawah Baru experimental site is located on 207 m above the sea level. The highest weekly rainfall during the experiment was 150 mm, air temperature was 25.50-27°C and humidity was 76-90%. Irrigation was applied according to weather condition (Figure 1).

Soil in the experimental site is classified as latosol, containing 9.7% sand, 38.5% dust, 51.8% clay, and categorized as acidic with H_2O pH of 5.0 (Table 2). Total of N-content, P, K, C-organic and Ca were classified as moderate, very high, low, low and medium, with medium cation and Mg exchange capacity (Table 2). In general, the level of soil fertility in the experimental land is classified as moderate, therefore additional fertilizer was expected to increase the growth and yield of upland rice "IPB 9G". The results of soil analysis at the end of this study showed that soil N, P and K increased compared to pre experiment (Table 3). This result showed that fertilizing with N, P, K increased nutrient availability in the soil even though N and P tended to decrease due to the uptake by the crops, or washed by rainwater. In this experiment, availability of soil N and P was classified from low to high, whereas the availability of K was classified as moderate to very high.

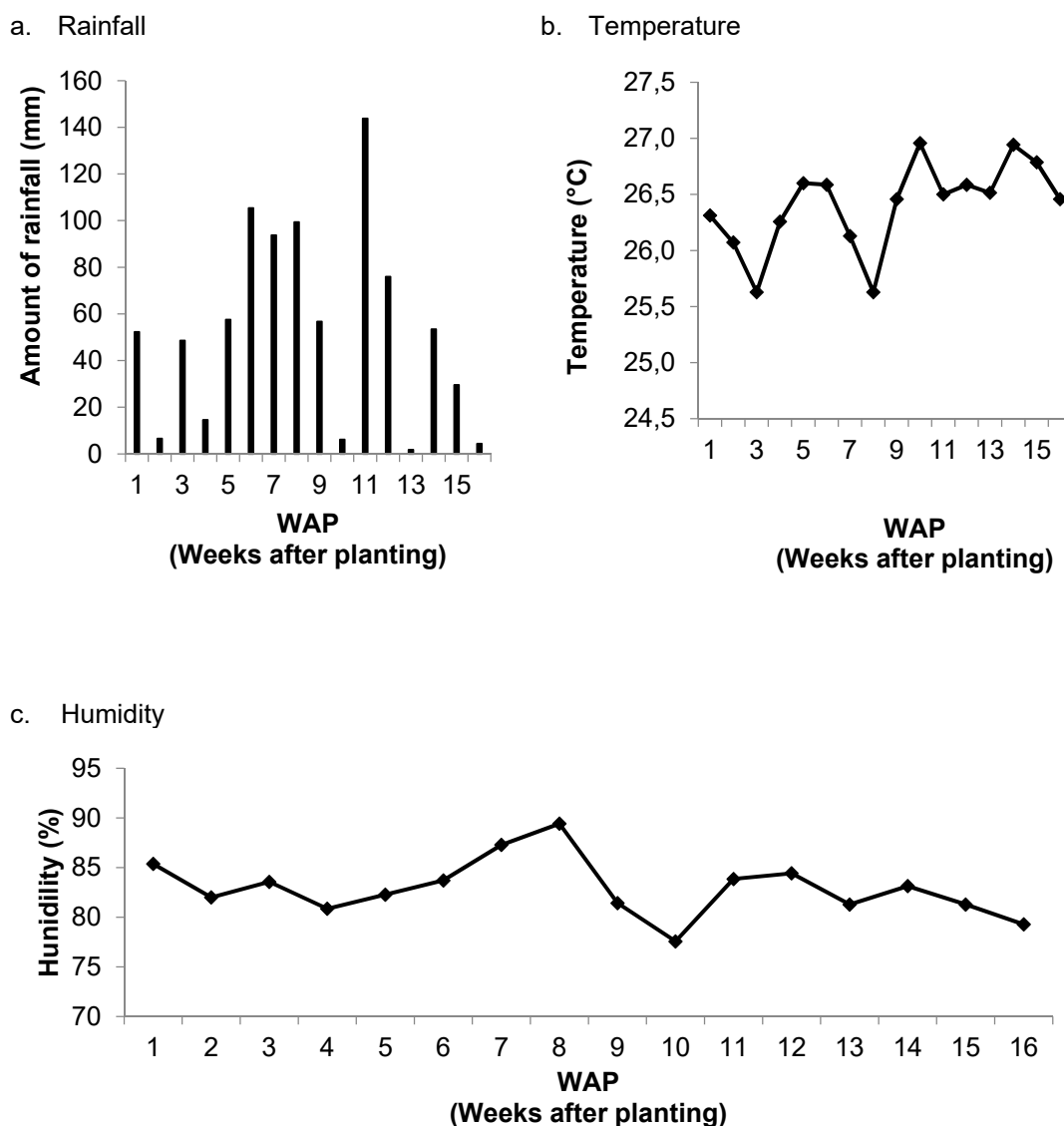


Figure 1. Rainfall (a), average temperature (b), and humidity (c). Source: BMKG Dramaga Climatology Station, Bogor

Table 2. Sawah baru soil analysis prior to the experiment*

Soil characteristic	Value	Status
pH	5.0	Acid
C-organic (%)	1.77	Low
N-total (%)	0.27	Moderate
C/N	7	Low
P ₂ O ₅ Bray (ppm)	17.0	Very high
KTK	19.21	Moderate
Ca (me/100g)	6.94	Moderate
Mg (me/100g)	1.62	Moderate
K (me/100g)	0.16	Low
Na (me/100g)	2.30	Very high
Base saturation (%)	57.40	Moderate

* Data was obtained from SEAMEO BIOTROP Soil Laboratory

Table 3. Sawah baru soil analysis after the experiment*

Treatment (%)	Nutrients			Status		
	N (%)	P (ppm)	K (ppm)	N (%)	P (ppm)	K (ppm)
N0	0.20	8.17	79.21	Low	Moderate	Very high
N50	0.20	9.04	99.01	Low	Moderate	Very high
N100	0.24	11.13	59.41	Moderate	High	Very high
N150	0.23	11.30	84.16	Moderate	High	Very high
N200	0.20	10.78	71.78	Low	Moderate	Very high
P0	0.24	6.96	47.03	Moderate	Low	High
P50	0.17	5.22	39.60	Low	Low	High
P100	0.27	4.87	56.93	Moderate	Low	High
P150	0.29	5.74	37.13	Moderate	Low	High
P200	0.36	6.43	49.50	Moderate	Low	High
K0	0.24	4.35	34.65	Moderate	Low	Moderate
K50	0.26	5.39	44.55	Moderate	Low	High
K100	0.18	9.22	42.08	Low	Moderate	High
K150	0.24	4.87	51.98	Moderate	Low	High
K200	0.20	5.04	44.55	Low	Low	High

*Data was obtained from Laboratory of the Department of Soil Sciences and Land Resources of IPB

Plant Height, Number of Tillers and Leaf Area

Increasing of N doses from 0 to 200% from the reference rate linearly increased plant height, but it was not significantly affect the number of tillers and leaf area (Table 4). Since the soil nutrient status was categorized as moderate (0.27%), N supply is still required. Nitrogen is the basic component of chlorophyll and can increase the plants' photosynthetic capacity, hence plant growth (Anhar et al., 2016). N is also involved in the formation of protoplasm, as a constituent of plant cell structure and cell division (Hernita et al., 2012).

Increasing the dose of P from 0 to 200% of the reference rate had positive correlation with development of leaf area. According to Karamanos et al. (2010) leaf area affects light interception during photosynthesis, so greater leaf area will increase photosynthesis, resulting in better plant growth. Increasing the K dose from 0 to 200% of the reference rate increased the leaf area, but did not affect plant height and number of tillers (Table 4). K also plays an important role in water absorption and can improve plant resistance to drought (Karamanos et al., 2010). Water shortages that last for a long time can hamper cell enlargement due to a decrease in the rate of photosynthesis,

protein synthesis, and resulted in smaller leaf area (Toha et al., 2002). K is also important for enzyme activation during photosynthesis, and regulating stomata opening and closing (Song and Banyo, 2011).

Canopy Biomass Dry Weight

Increasing the N dose from 0 to 200% of the reference rate tended to increase dry weight of canopy biomass at the vegetative phase, especially at heading and harvesting time. Bustami et al. (2012) demonstrated that optimum application of fertilization had a good impact on plant growth and dry weight of canopy biomass. Furthermore, increasing of N dose also related to N content in the soil. In this study, soil analysis was categorized as moderate (0.23-0.27%) before and after N application. Sarif et al. (2015) reported that N deficiency decreases plant growth, whereas excessive N causes pollution to the environment.

Treatments with P and K fertilizer doses of 0-200% of the reference increased canopy dry weight at the vegetative, primordia, heading and harvesting phases. Soil nutrients availability will support absorption by the plants resulting in a better canopy growth. Anisyah et al. (2014) stated that availability of P in the soil is associated with the application of P fertilizer. K availability supports photosynthesis through photophosphorylation which produces ATP and NADPH (Novizan, 2002), resulting in greater dry weight of plant biomass (Gardner et al., 2017).

Yield and Yield Components

Increasing N fertilizer doses from 0 to 200% from the reference rate increased the number of productive tillers, harvest index and grain weight per clump, whereas the number of grains per panicle was not significantly affected. Number of tillers in the treatment of 200 kg.N⁻¹ showed the highest value compared to the other N treatments. However, increasing of N dose reduced harvest index; application of N at 200%

Table 4. The effects of increasing N, P, K doses from 0 to 200% of the reference rate on plant height at 10 WAP, number of tillers at 8 WAP and leaf area at heading phase

Treatment (%)	Plant height (cm)	Number of tillers (stem)	Leaf area (cm ²)
	10 WAP	8 WAP	Heading
N0	108.71	12.20	1799.38
N50	114.05	13.33	4786.35
N100	118.46	12.93	3198.66
N150	120.53	15.20	4501.70
N200	124.73	15.13	5585.15
Pr>F	0.0112	0.0853	0.0707
Response pattern ^t	L*	ns	ns
P0	127.51	11.30	1724.87
P50	124.72	11.93	2559.52
P100	124.97	11.53	2404.40
P150	124.35	13.00	2212.93
P200	122.15	12.20	2846.69
Pr>F	0.3545	0.4713	0.0064
Response pattern ^t	ns	ns	L**
K0	121.89	10.45	1786.23
K50	124.19	11.67	2748.58
K100	125.72	10.67	3224.81
K150	129.15	11.73	2920.28
K200	127.98	10.93	3766.72
Pr>F	0.2399	0.2566	0.0139
Response pattern ^t	ns	ns	L*

Note: t: orthogonal polynomial test for fertilizer dosage; L: linear; ns: not significantly different; *: significantly different at $\alpha = 0.05$; **: significantly different at $\alpha = 0.01$

Table 5. The rice dry weight of canopy biomass at the vegetative, primordia, heading and harvesting phase

Treatment (%)	The dry weight of the canopy biomass (g)			
	Vegetative	Primordia	Heading	Harvest
N0	5.34	21.61	35.90	20.35
N50	8.42	24.94	49.82	24.87
N100	10.52	27.97	59.27	28.17
N150	10.28	32.61	66.61	27.59
N200	10.16	27.73	81.84	28.68
Pr>F	0.0717	0.2058	<.0001	0.0395
Response pattern ^t	L+	ns	L**	L*
P0	9.92	24.17	49.59	18.05
P50	11.64	27.24	62.44	21.27
P100	13.04	28.69	64.48	20.56
P150	14.77	35.51	68.61	25.03
P200	16.19	36.65	79.16	25.25
Pr>F	0.0070	0.0357	0.0022	0.0045
Response pattern ^t	L**	L*	L**	L**
K0	8.93	17.38	50.41	22.96
K50	10.18	34.54	59.02	27.16
K100	11.61	31.05	59.68	25.17
K150	11.85	36.99	67.16	28.71
K200	13.50	37.45	86.63	28.25
Pr>F	0.0066	0.0202	<.0001	0.0133
Response pattern ^t	L**	L*	L**	L*

t: orthogonal polynomial test for fertilizer dosage; L: linear ; ns: not significantly different; *: significantly different at $\alpha = 0.05$; **: significantly different at $\alpha=0.01$

of the reference rate produced a low harvest index compared to 100% of the reference. Proportionally, grain weight was lower than canopy dry weight, whereas the harvest index value tended to decrease in line with increasing of total dry weight of plants. N is the main constituent of protein ingredients, and has important roles in chlorophyll formation and photosynthesis processes, resulting in the promotion of plant height, number of tillers, increasing size and grain, improving plant and grain quality, increasing protein content, as well as the amount and the percentage of grain contents (Misbahudi et al., 2017). Manurung and Ismunadji (1988) reported that the range of rice crop index to obtain high yield was ± 0.5 .

P fertilizer 0 to 200% of the reference rate generally did not affect the number of productive tillers, the number of grain per panicle, harvest index, and grain weight per clump. However, the excessive nutrient levels over plant needs only caused an increasing of P level in the soil and no longer effect on plant growth. Similar with N, optimum level of P correlates positively with P availability in the soil (Fitriatin et al.,

2008). Furthermore, Setiawati et al. (2016) reported that phosphate levels in the soil can be increased by fungi; fungi possess phosphatase enzymes which can hydrolyze inositol hexaphosphate.

Increasing of K doses from 0 to 200% from the reference rate increased grain number per panicle and grain weight per clump and harvest index, but did not affect the number of grain per panicle. K plays an essential role in translocating assimilates from leaves to all plant organs whereas can accelerate photosynthesis (Muslim, 2017). The best timing of potassium absorption on rice plant is tillering which can increase the number of panicles and grain, and in the primordial phase which helping the increment of both weight and yield of grain (Salbiah et al., 2012). Hardjowigeno (2003) stated that potassium is very important in plant physiology processes. Lubis (2018) demonstrated that application of higher concentration of K increased the circumference of Belitung taro (*Xanthosoma sagittifolium* (L.) stem.

Table 5. Yield and Yield Components

Treatment (%)	Number of productive tillers	Number of grain per panicle	Harvest index	Grain weight per clump (g)
N0	9.56	210.03	0.40	49.73
N50	10.44	210.38	0.37	100.72
N100	11.44	215.59	0.41	89.38
N150	11.11	211.51	0.35	83.16
N200	13.89	226.69	0.26	105.06
Pr>F	0.0033	0.5447	0.0062	0.0027
Response pattern ^t	L**	ns	L**	L**
P0	9.89	202.69	0.41	65.48
P50	12.44	224.69	0.43	93.41
P100	11.44	220.29	0.37	93.13
P150	11.78	245.20	0.42	98.62
P200	12.11	231.69	0.41	88.20
Pr>F	0.1799	0.1625	0.2246	0.1404
Response pattern ^t	nsd	nsd	nsd	Nsd
K0	11.22	216.54	0.45	93.48
K50	13.00	229.28	0.35	87.69
K100	12.44	232.10	0.43	97.25
K150	12.22	237.35	0.41	104.42
K200	13.22	260.46	0.47	116.86
Pr>F	0.3675	0.0254	0.0186	0.0368
Response pattern ^t	ns	L*	Q*	L*

t: orthogonal polynomial test for fertilizer dosage; L: linear ; ns: not significantly different; *: significantly different at $\alpha = 0.05$; **: significantly different at $\alpha=0.01$

Recommendations for N, P and K for Rice "IPB 9G"

Fertilizer recommendations were made based on grain weight per upland rice clump of the "IPB 9G". The yields were converted into relative results so that the three trials could be compared. Fertilization recommendations cannot be determined by a multi-nutrient response approach as the observation characters with quadratic curves are only found in the N and P experiments on the grain weight per clump (Figure 2). Therefore the fertilizer recommendations were determined using the optimum dose range of the growth variables.

Based on the quadratic equation of relative results (Figures 2a and 2b) the optimum dose of N was 107.9 kg N.ha⁻¹, and the optimum dose of P was 63.3 kg P₂O₅.ha⁻¹. The optimum dose of K could not be determined because a negative value of -11.27 kg K₂O ha⁻¹ was obtained. The relative yield of "9G

IPB" upland rice, which consists of relative value of N, P and K, are described in Figure 2a, 2b and 2c, respectively. The relative yield showed that grain weight per clump was significantly affected by N and P fertilization treatments with quadratic response pattern, whereas the grain weight per clump was affected by K fertilization treatment with linear response pattern.

Conclusion

The optimum dose of K fertilizer can not be determined from this experiment. The optimum doses of N and P fertilization for upland rice "IPB 9G" in Sawah Baru were 107.09 kg N.ha⁻¹ and 63.3 kg P₂O₅. ha⁻¹, respectively.

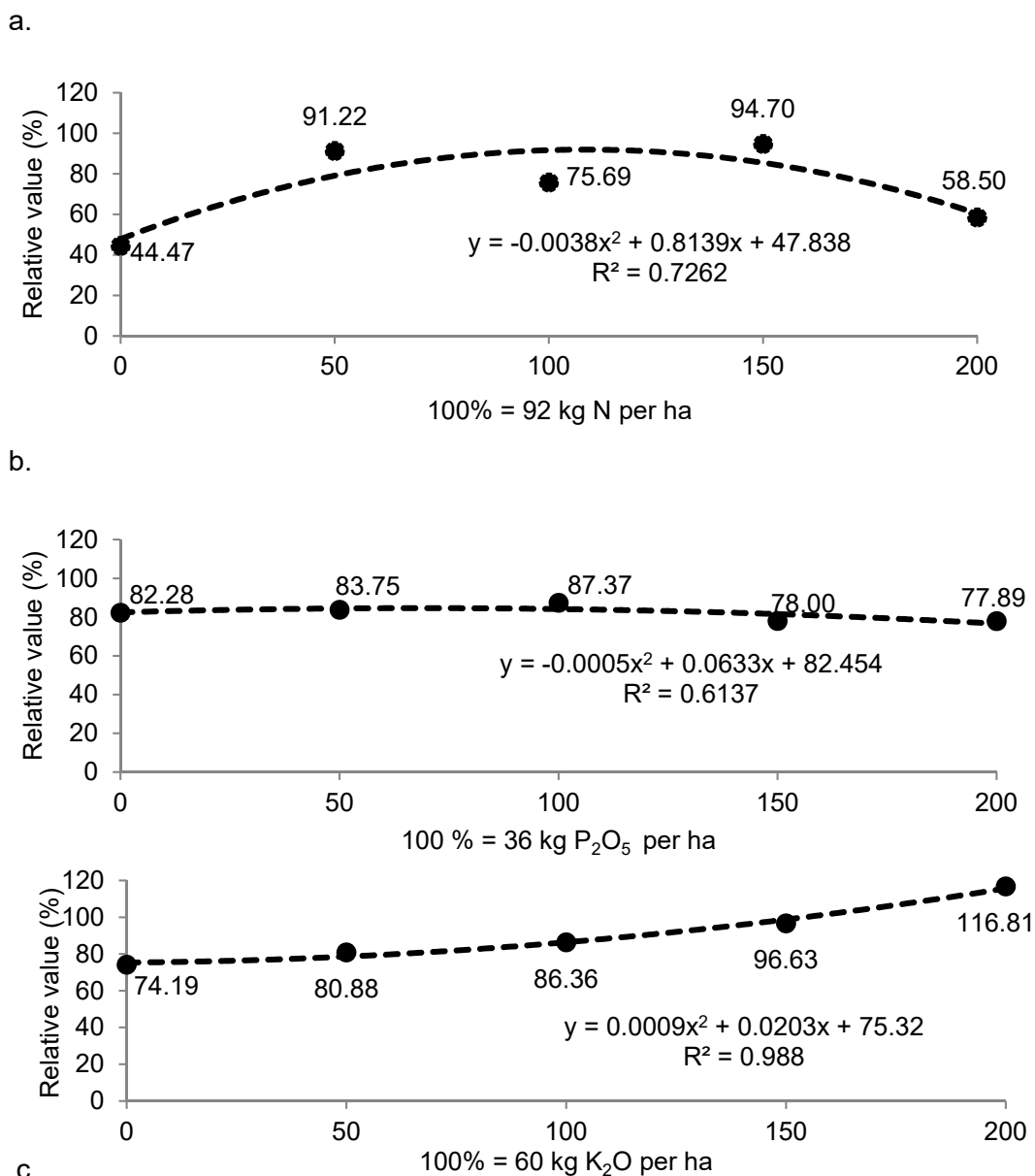


Figure 2. The relative value of grain weight per experimental group; N (a), P (b), and K (c)

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