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Rates and split top-dress applications of N fertilizer in the production of sweet potato in tropical soil

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Abstract

There are some studies about plant nutrition and split topdress application of fertilizer to influence nutrients and production of sweet potatoes. This study aimed to evaluate the influence of nitrogen doses in the presence or absence of split topdress application on production of sweet potato. A field experiment was conducted at São Manuel Experimental Farm. The experimental design was a randomized complete block with seven treatments (2×3+1 factorial design) and five repetitions. Treatments consisted of three doses of N topdressing (30, 60 and 90 kg Nha^{-1}), two application time (30 and 50 days after shoots sprouting) and a control (without N topdressing). The analysis evaluated roots fresh and dry matter, number of roots, roots length and diameter, roots productivity and the capacity of roots to extract macronutrients. A higher production was observed with multiple application of N fertilizer with 1146.3 g of root per plant. On the other hand, the single application produced an average of 926.7g per plant. A quadratic adjust was obtained with an average of 1209.2 g at 69.2 kg N ha^{-1} from the single application. However, the yield per hectare did not show any statistical significance in the presence (47.8 t ha^{-1}) or absence (40.1 t ha^{-1}) of split application. The average yield in single application was 52.5 t ha^{-1} at 75.0 kg N ha^{-1}. On the other hand, the split application produced 54.7 t ha^{-1} at the highest estimated dose of 85.0 kg N ha^{-1}. The N topdressing reached a statistical significant difference in most of the analysed features. Moreover, the best results obtained from N doses ranging from 60 to 70 kg ha^{-1}.

Keywords: *Ipomoea batatas* L .; macronutrients; nitrogen; nutrition; production.
Abbreviations: CEC_ cation exchange capacity; L_ length; CV_ coefficient of variation; DAP_ days after planting; DMH _ dry matter per hectare; DMP_ dry matter per plant; O.M_ organic matter; NR_ number of roots per plant; NRH _ number of roots per hectare; P_ productivity; PP_ production per plant; SB_ sum of bases; V_ base saturation.

Introduction

Sweet potato has economic and social importance to producers due to its popularity and fewer resources that requires compared to other crops. It is an important source of nutrients to human health. Thus, this crop is present in many poor areas (Fuglie, 2007; Low et al., 2007, Fetuga et al., 2013).

Additionally, the development of a sustainable and productive agriculture is associated with the best fertilization management practice, involving appropriate nutrient management, right source of fertilizer and the best application time (Fageria and Baligar, 2005). Moreover, management practices can increase nutrient uptake to meet the plant's needs. The management practices also improve the capacity of the soil by adding minerals, allowing the mineralization of organic matter. The doses of nitrogen can enhance plant performance, consequently, improving plants development and production (Westermann et al., 1994; Neeteson and Carton, 2001; Rahn, 2002; Sady et al., 2008; Fontes et al., 2010; Öztürk et al., 2010).

The use of nitrogen requires a special attention when applied into the soils cultivated by sweet potatoes under tropical conditions, because these soils present high concentrations of N, causing an intense growth of the shoots at the expense of tuberous roots formation. However, different varieties of sweet potatoes respond differently to N doses, e.g. some develop better the roots, while others produce lush green vegetation (Oliveira et al., 2006). There are a few studies showing the right level of N in order to obtain satisfactory yields of sweet potato. Thus, the effect of N on sweet potato suggests to be split-applied, i.e. by applying 1/3 at planting and the rest in 30 to 45 days as topdressing. The recommended doses for soils with high, medium and low fertility are 100, 60 and 30 kg N ha^{-1}, respectively (Oliveira et al., 2006). The amount of nitrogen should be split-applied according to the plant's real needs. Thus, a portion of N fertilizer should be applied at planting and another portion on later. According to Buchanan et al. (2015) nitrogen is part of proteins, nucleic acids and other important cellular components, including membranes and various plants hormones. A response of sweet potato to fertilization depends on soil conditions. Tropical regions are characterized by weathered soils, greater intensity of rain and acidic soil, which facilitates leaching of N, by which the N main rates are elevated.

The aim of this study is to evaluate the effects of different rates of split top-dress N fertilizer application on production of sweet potato in Tropical soil.

Results and Discussion

Production of roots

Regarding to the roots fresh mass, there was a statistically significant difference between doses and split applications. The largest root matter (277 g root $plant^{-1}$) achieved at 90 kg N ha^{-1} (Table 1). However, a quadratic function for maximum average estimated in 249.8 g $root^{-1}$ at 46.9 kg ha^{-1} after single application of N fertilizer. However, when the nitrogen fertilizer was split into 30 and 50 days after sprouting, a linear increase was observed (Fig. 1). Thus, the split-applying of N fertilizer can possibly favour the development of tuberous roots, occurring less leaching which is intense in sandy soils of this study. These finding corroborates the Alves et al. (2009), who reported average matter of commercial sweet potato roots of (198.0g) in the single application of N (as ammonium sulphate at planting). But the highest average matter (294g) was obtained with multiple application of N, as urea (50% at planting and 50% at 30 DAP). On the other hand, Oliveira et al (2013), evaluating the average matter of commercial sweet potato roots, obtained maximum values of 264.9 and 197.6g in the presence of goat manure (39.8 t ha^{-1}) and chicken manure (12.9 t ha^{-1}), respectively.

Regarding to the roots diameter, there was a statistical difference between doses and split application. The root diameters of 55.5 mm and 49.0 mm were achieved by single and split application at 30 kg N ha^{-1}, respectively. It looks that split-applying the lowest dose of N (30 kg N ha^{-1}) may have reduced the macronutrient availability in the developmental period, i.e. growth in roots diameter (Table 1). However, a linear increase was obtained in both single and split applications (Fig. 1).

For the number of commercial roots per plant, split N application reached the highest value (4.7), while the lowest value (4.0) observed for the single application (Table 2). In relation to the doses of N, a quadratic function was obtained with and without multiple applications, showing an average of 5.1 roots per $plant^{-1}$ at 56.4 kg N ha^{-1} in single application; and a maximum average estimated in 4.8 roots per $plant^{-1}$ at 75 kg N ha^{-1} (Fig. 1). Alves et al. (2009), evaluated sources and split application of N fertilizers. They reported the highest numbers of commercial roots per plant in sweet potato when N (i.e. ammonium sulphate) was single applied at planting (100%); 50% at planting and 50% at 30 DAP; 33% at planting, 33% at 30 DAP and 33% at 60 DAP; and 100% at 60 DAP. However, by applying urea as a source, regardless of the single or split application, no significant changes in the number of roots was presented and all averages were lower than ammonium sulphate (Alves et al., 2009).

The excess of N fertilizer may affect the formation of commercial roots due to the high lush vegetation production and the adventitious roots development in sweet potato. Thus, the higher the availability of N on sweet potato, the more the influence of this macronutrient on roots formation (Chaves and Pereira, 1995) due to the toxic effect of ammonia from urea and reduction of plant uptake for other cations (K +, Ca ++, Mg ++).

Regarding to the roots length, there was no statistic difference in both applications, with an average of 19.1 cm (Table 2). For the doses of N, a quadratic function was observed in single application, with an estimated average of 19.5 cm at 57.1 kg N ha^{-1}. When the application of N was split into 30 and 50 days after sprouting, a linear increase was observed (Fig. 1). According to Fernandes (2006), N is one of most limiting factors of plant growth. This fact was confirmed in this study, because there were variations in the roots dimensions in relation to the doses of N, regardless of treatments. However, higher single doses of N were extremely harmful to the roots length, when split application was not performed.

With regards to the the production per plant, higher production was observed with multiple application of N fertilizer, i.e. 1146.3 g (Table 2). On the other hand, the single application presented an average of 926.7 g. A quadratic adjust was obtained with an average of 1209.2 g at 69.2 kg N ha^{-1} in the single application. However, a linear increase was observed by split-applying N (Fig. 1). Alves et al. (2009), evaluated the N sources and split N application. They found that the grain yield of commercial roots per plant provided higher values, especially by split-applying into three times, producing 337.75g of roots per plant. However, smaller productions were obtained when urea was single applied, possibly by causing nutrient leaching. According to Cardoso et al. (2007), when the application of N and K was split, it influenced the productivity of potato tubers (*Solanum tuberosum*). The best response was obtained with the third split application (i.e. 50% at planting and 50% in the tuber initiation) compared to no split application; and the fifth split application (1/4 at sowing; 1/4 at tuber initiation; 1/4 25 days after the tuber initiation; and 1/4 50 days after tuber initiation).

Regarding the number of roots per hectare, 167,708 roots were obtained in the single application and 195,277.8 in the presence of split application, reaching a difference of 27,569 only in one hectare (Table 2). In relation to the doses, a quadratic adjust did not reach a statistical significance for the number of commercial roots per hectare. After single application, the average was 201,820.6 roots per hectare at 69.6 kg N ha^{-1}. In the presence of split application, it was 219,774.9 of commercial roots per hectare at 56 kg N ha^{-1}. This pattern was also observed for the yield per hectare, which did not reach any statistical significance in the presence (47.8 t ha^{-1}) or absence (40.1 t ha^{-1}) of split application. The average yield in single application was 52.5 t ha^{-1} at 75.0 kg N ha^{-1}. In split application, the average yield was 54.7 t ha^{-1} at the highest estimated dose of nitrogen (85.0 kg N ha^{-1}). According to Buchanan et al. (2015), N influences processes that involve growth and development, having direct effect on source-path-sink transport and changing the distribution of assimilates between vegetative and reproductive structures.

Regarding to roots dry mass per plant and per hectare, there was no statistical difference with an average of 230 g and 9.6 t ha^{-1}, respectively (Table 2). With regards to the doses of N, a quadratic adjust was obtained for both the presence and absence of split application. For the single application, the maximum average was estimated in 265.5 g $plant^{-1}$ at 61.3 kg N ha^{-1}. After sprouting, the nitrogen fertilizer was split-applied after 30 and 50 days, obtaining an average maximum in 280.6 g $plant^{-1}$ at 75.0 kg N ha^{-1}. N is the macronutrient responsible for the plants growth; therefore, by increasing the doses of N to some extent it becomes favourable to accumulate the dry matter. A similar behaviour was observed for root dry mass per hectare that presented an average of 11.1 t ha^{-1} (at 60.6 kg N ha^{-1}) in the single application; and 11.5t ha^{-1} (at 76 7 kg N ha^{-1}) in the split application (Fig. 1).

Table 1. Roots fresh matter (g) and roots diameter (mm) with split topdress and without (single) applications at different doses of N fertilizer in the production of sweet potato, FCA/UNESP, São Manuel, SP, 2014.

Root dry matter (g)			
Split topdress application	30	60	90
Without (Single application)	256.0 a	239.6 a	236.6 b
With (Split topdress)	206.4 b	262.4 a	277.6 a
Root diameter			
Without (Single application)	55.5 a	55.0 a	55.3 a
With (Split topdress)	49.4 b	51.9 a	58.0 a

*Means followed by different letters differ by Tukey test at 5% probability.

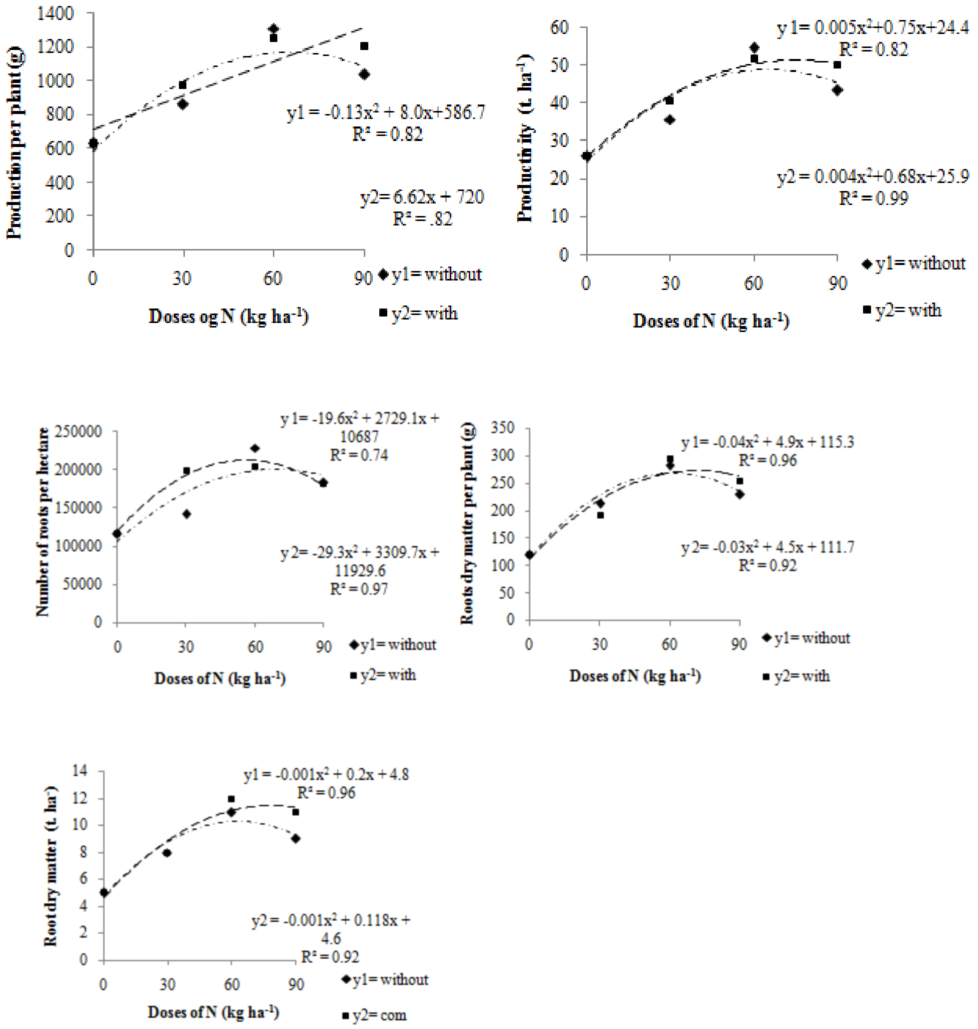
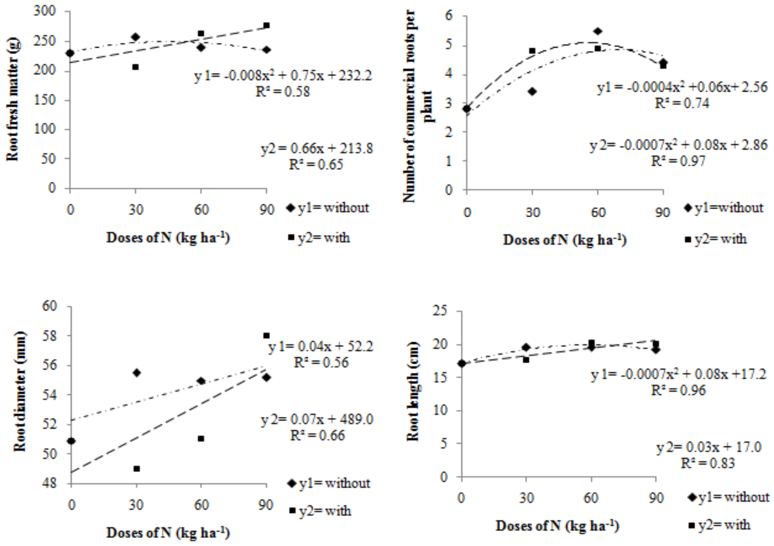


Fig 1. Fresh matter, number of commercial roots per plant, diameter, length, plant production, productivity, number of roots per hectare, plant dry matter and roots dry matter per hectare with split topdress applications at different doses of N fertilizer in the production of sweet potato,FCA/UNESP, São Manuel, SP, 2014.

Table 2. Number of roots per plant (RP), length (L_cm), production per plant (PP_g), productivity (P_t ha^{-1}), number of roots per hectare (NRH), plant dry matter (PDM_g) and dry matter per hectare (DMH_t ha^{-1}) with split topdress applications at different doses of N fertilizer in the production of sweet potato,FCA/UNESP,São Manuel, SP, 2014.

Split application	RP	L (cm)	PP (g)	P (ha)	NRH	PDM (g)	DMH
Without (Single)	4.0 b	18.8 a	962.7 b	40.1 b	167708.3 b	211.9 a	8.8 a
With	4.7 a	19.4 a	1146.3 a	47.8 a	195277.8 a	248.1 a	10.3 a
CV (%)	13.91	8.31	10.20	10.20	13.91	18.56	18.56

*Means followed by different letters differ by Tukey test at 5% probability.



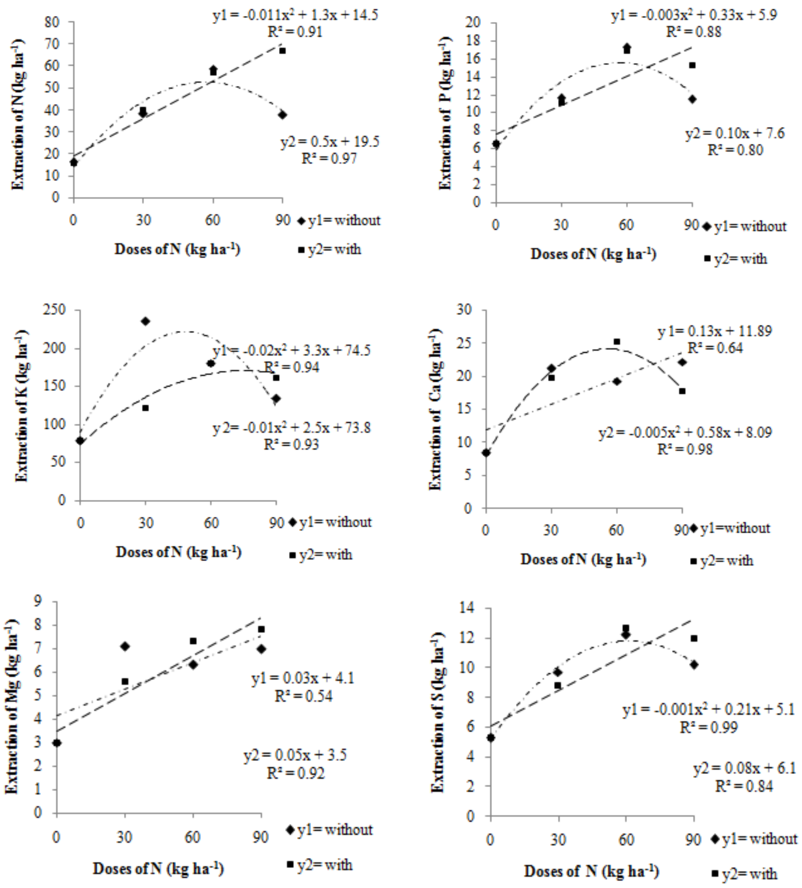


Fig 2. Extraction of macronutrients N; P; K; Ca; Mg and S with split topdress applications at different doses of N fertilizer in the production of sweet potato, FCA/UNESP,São Manuel, SP, 2014.

Table 3. Macronutrients extraction (kg ha^{-1}) with split topdress applications at different doses of N fertilizer in the production of sweet potato, FCA/UNESP, São Manuel, SP, 2014.

Split application	N	P	K	Ca	Mg	S
Without (Single)	38.1 b	11.7 b	132.4 a	17.8 a	5.9 a	9.4 a
With	55.3 a	14.1 a	154.8 a	20.9 a	6.9 a	11.2a
CV (%)	27.30	21.24	17.74	50.70	29.15	20.53

*Means followed by different letters differ by Tukey test at 5% probability.

Extraction of macronutrients

For the extraction of macronutrients in kg ha^{-1}, no interaction between doses and split application of N fertilizer was observed. Regarding to the split application, an average of 55.3 kg ha^{-1} by split-applying the N and 38.1 kg ha^{-1} by single-applying were observed (Table 3). For N extraction, a quadratic function reached an average estimated in 55.4 kg ha^{-1} at 60.9 kg N ha^{-1}in single application. However, when the application was split, a linear increase was observed (Fig. 2). In general, N is one of the nutrients absorbed in larger quantities and has a direct influence on the growth and development of the plants (Fernandes, 2006).

The same behaviour has been observed for P with an average of 11.7 kg ha^{-1} in single application and 14.1 kg ha^{-1} in split-applying (Table 3). For the doses of N, a quadratic function reached an average of 15.6 kg ha^{-1} at 56.7 kg ha^{-1} in single application. However, a linear adjustment with the split application was observed (Fig. 2).

For K^+, $Ca^{2+,}$ Mg^{2+} and SO_4^{2-}, there was no statisticaly significant difference with regards to the split application of N, showing the following averages of 143.6; 19.4; 6.4 and 10.3, respectively (Table 3).

In relation to potassium, a quadratic effect was obtained for both cases. In the absence of split application, the maximum average was estimated in 168.8 kg ha^{-1} at 57.9 kg ha^{-1}. However, by split-applying the average was estimated as 170.2 kg ha^{-1} at 76.6 kg ha^{-1} (Fig. 2). Cantarella (2007) emphasized that by the application of manure, the most common interactions related to nitrogen are occurring with potassium. Furthermore, both nutrients are absorbed in relatively high proportions to almost any crop species and usually have non-competitive association. The author emphasized that the balanced supply of nitrogen and potassium often increases both responses; although the opposite can also happen. This means that if there is no addition of K or N into a deficient soil, it can decrease the response to one of them. Regarding to Ca, a linear adjustment was observed in single application and a quadratic function with an average of 24.9 kg ha^{-1} at 58.0 kg N ha^{-1} in the presence of the split application. For the Mg, a linear adjustment for both applications was observed. For S extraction, a quadratic function with an average 11.5 kg ha^{-1} at 60.0 kg ha^{-1} was estimated for in the single application; and a linear increase by split-applying (Fig. 2).

Materials and Methods

Location and soil classification

The plants were cultivated in the Sao Manuel Experimental Farm, Botucatu School of Agronomy, UNESP (22°46'S, 48°34'W; 740m altitude; climate type Cwa, according to Köppen’s classification). The mean annual rainfall of São Manuel is 1445 mm; and the mean annual temperature is 21°C. The soil is classified as Dystrophic Red Latosol (Oxisoil).

Soil samples were collected from depth of 0-20 cm to determine their chemical properties: pH in $CaCl_2$, 5.6; O.M. 9 g dm^{-3}; Presin 88 mg dm^{-3}; H+Al 18$mmol_c dm^{-3}$; K 2.0 $mmol_c dm^{-3}$; Ca 33 $mmol_c dm^{-3}$; Mg 10$mmol_c dm^{-3}$; SB 45$mmol_c dm^{-3}$; CTC 63mmolcdm^{-3} and V% 71.

Plant material and experimental design

The experimental design was a randomized complete block with seven treatments (2×3+1factorial design) and five repetitions. Treatments consisted of three doses of N topdressing (30, 60 and 90 kg ha^{-1}); two applications time (30 and 50 days after sprouting), which is corresponded to the split topdressing and a control (without N topdressing). There were eight plants per plot, consisting of three rows with ten plants each, but the two side rows were considered as borders.

Considering the soil classification, 20 kg N ha^{-1} and 60 kg $P_2O_5ha^{-1}$ at planting was applied, according to the methodology described by Raij et al. (1997).

The Canadian range was used. The sprinkler irrigation was carried out and harvesting was held on July 28, 2014. The roots were brought into the Fruits and Vegetables Post-Harvest Laboratory (Department of Horticulture) to evaluate roots fresh and dry matter, plant productivity, number of roots per plant and per hectare, roots diameter and length, and roots capacity to extract macronutrients. To obtain the nutrient content (N, P, K, Ca, Mg and S) in the shoots of sweet potato plants, two plants were sampled per plot. Once collected, the samples were transferred to the Plants Analysis Laboratory in the Department of Soil and Environmental Resources (UNESP). After washing the samples, they were placed in paper bags and taken to dry in a forced-air-circulation oven at 65°C until constant mass, according to Malavolta et al. (1997). Subsequently, the dry matter from each plant was weighted using the analytical balance.

Then, each sample was ground through a Wiley mill. The two digestion methods were sulphuric acid to determine N values. The P, K, Ca, Mg and S were determined through nitric-perchloric acid, according to the methodology described by Malavolta et al. (1997).

Regarding the chemical analyzes, nitrogen, phosphorus, potassium, calcium, magnesium and sulphur were measured in g kg^{-1}. The amount of nutrient extracted has been obtained by multiplying the content of each nutrient by the sample dry mass.

Statistical analysis

Results were subjected to analysis of variance. The comparison of means (in case of significant effects) on levels of nitrogen was done by F-test and regression analysis.

Conclusion

An average of 1209.2 g of root was obtained at 69.2 kg N ha^{-1} in the single application method. The average yield in single application was 52.5 t ha^{-1} at 75.0 kg N ha^{-1}. On the other hand, in split application was 54.7 t ha^{-1} at the highest estimated dose of 85.0 kg N ha^{-1}. The split topdress applications of N fertilizer favoured most of the analysed features. The best results were achieved ranging from 60 to 70 kg N ha^{-1}.

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