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Influence of Nitrogen Application Rates on Yield and Yield Attributes of Long Duration Varieties of Cassava (*Manihot esculenta* Crantz)

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ABSTRACT

A field experiment was carried out at ICAR- Central Tuber Crops Research Institute (CTCRI), Sreekariyam, Thiruvananthapuram, Kerala, India to investigate the effect of different nitrogen application rates on yield and yield attributes of two long-duration cassava varieties during March, 2021 to February, 2022. The experiment was set up in Factorial Randomized Block Design (FRBD) with three replications involving two factors- two cassava varieties (Sree Pavithra and Sree Reksha) and five different nitrogen application rates (0%, 25%, 50%, 100% and 125%) of recommended nitrogen dose of 100 kg ha^{-1}. The study revealed that the application of super optimal dose of nitrogen (125%RD of nitrogen @ 125 kg ha^{-1}) significantly increased the yield (52.61 t ha^{-1}) and yield attributes namely number of tubers (3.55) plant^{-1}, average lenth of tuber (25.48 cm), average diameter of the tuber (12 cm) and average tuber yield plant^{-1} (4.24 kg) in cassava. Also, super optimal dose of nitrogen positively influenced SPAD 502 chlorophyll meter reading (45.13), leaf chlorophyll a content (1.52, 1.72 mg g^{-1}), chlorophyll b (0.64, 0.72 mg g^{-1}) content and total chlorophyll content (2.20, 2.49 mg g^{-1}), leaf carotene content (0.42, 0.48 mg g^{-1}) in V_1 (Sree Pavithra) V_2 (Sree Reksha) respectively. Super optimal level of nitrogen positively influenced nitrogen content in leaf,stem and tuber along with phosphorous and potash content in both varieties of cassava.

KEYWORDS: Cassava, carotene, chlorophyll, growth, nitrogen, plant, variety, yield

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1. INTRODUCTION

Cassava (*Manihot esculenta* Crantz), a drought-tolerant staple food crop and the third-largest source of food carbohydrates in the tropics, after rice and maize. This is a native of South America, only cultigen in the Euphorbiaceae family, and widely cultivated in tropical and sub-tropical areas around the world (Latif and Muller, 2014, Li et al., 2017). Cassava plays an important role as staple food for more than 500 million people in the world due to its high carbohydrate content (Blagbrough et al., 2010), it's also vital as feed and industrial raw material, as well as an energy source, making it ideal for cascade use (Reilly et al., 2004, Latif and Muller, 2014, Rahman and Awerije, 2016). Being the third most important source of calories in the tropics, cassava has a higher starch accumulation capacity (121 mJ ha^{-1} day^{-1}) (Horton and Fano 1985, Edison, 2006), drought tolerance and resistance to low soil nutrient levels than other starchy crops, allowing it to be produced in regions where other crops fail to survive (Howeler, 2012, Li et al., 2017). Cassava is considered as "all sufficient" in Congo because people get "bread" from the roots and "meat" from the leaves (Achidi et al., 2008). Cassava has some medicinal properties and it boosts energy level, ensures healthy weight gain, helps prevent Alzheimer's disease and cardiovascular diseases and useful for muscle growth and development maintaining optimal blood pressure (Chandrasekara and Kumar, 2016).

Cassava cultivated in 28.24 mha, with yield of 302.66 mt and productivity of 10.72 tha^{-1} globally in 2020 (Anonymous, 2020). Nigeria is the world's largest cassava producer, followed by Congo, Thailand, Ghana, and Indonesia, with India ranking fourteenth (Anonymous, 2020). In 2020, Tamil Nadu has the largest area (0.67 lha) under cassava cultivation in India with a production of 2.53 mt and productivity of 37.77 t ha^{-1} (Anonymous, 2021).

Farmers frequently cultivate cassava with little or no fertilizer. Even though cassava grows better on nutrient-deficient soils compared to other crops, it responds well to fertilizer application. To ensure that the crop receives the nutrients it requires for full growth and development, optimal nutrient management is necessary. Studies conducted by various researchers around the world comparing the yield of fertilized and unfertilized cassava revealed that yield can be boosted considerably through fertilizer application (Howeler and Cadavid, 1990, Cenpukdee and Fukai, 1991, Howeler, 2002, Mwamba et al., 2021).

The cassava plant can tolerate low levels of 'P' owing to its mycorrhizal association, however it requires fairly high levels of N and K (Howeler and Oates, 2000). Previous research has shown that higher nitrogen doses boosted yield and yield attributes considerably (Uwah et al., 2013, Sangakkara and Wijesinghe, 2014, Oliveira et al., 2017). According to Uwah et al. (2013), plant height was significantly increased, as were the number of leaves and branches plant^{-1}, stem girth, number and weight of tubers plant^{-1} and total fresh tuber output when N was applied at the highest rate (120 kg ha^{-1}).

Application of nitrogen up to a certain level increased the yield and yield attributes greatly however very high levels of nitrogen harm cassava yield. According to Omondi et al. (2019) 'N' application increased photosynthesis and yield up to a certain point, after which the canopy became too demanding and plants were forced to restrain transpiration, reduce photosynthesis, decrease carbohydrates, compromise carbohydrate allocation to storage in roots resulting in yield drops. The current study was aimed to study, how varying nitrogen application rates affect the yield and yield attributes of two long duration cassava varieties.

2. MATERIALS AND METHODS

A field study was carried out at ICAR-Central Tuber Crops Research Institute (CTCRI), Sreekariyam, Thiruvananthapuram, Kerala, India located at latitude of 8°32'42.74'' N and longitude of 76°54'53.72'' E. The experiment was conducted during March, 2021 to February, 2022. The experiment was set up in Factorial Randomized Block Design (FRBD) with 3 replications. The study involved two factors, two cassava varieties*viz.,*V_1 (Sree Pavithra,7.5–8 months duration) and V_2 (Sree Reksha,9–10 months duration) and five different Nitrogen application rates *i.e.,* 0% (N_0), 25% (N_1), 50% (N_2), 100% (N_3) and 125% (N_4) of recommended Nitrogen dose of 100 kg ha^{-1} while Phosphorous and Potassium are applied at 50 kg ha^{-1} and 100 kg ha^{-1} respectively for all treatments. A total of 10 treatments were formed by the combination of these two factors. Thus, the field has a total of 30 plots of equal size representing two cassava varietiesand five different nitrogen application rates. Cassava was planted with a spacing of 90×90 cm^2 resulting in 36 plants plot^{-1} (Minimum required plant density for conducting nutrient experiment of cassava. (Sunitha et al., 2020) (Table 1).

Table 1: Initial physicochemical properties of the experimental soil

Parameters	Unit	Value
Soil pH	-	5.98
Organic carbon	%	0.64
Nitrogen	kg ha^{-1}	151.57
Phosphorous	kg ha^{-1}	54.96
Potassium	kg ha^{-1}	272.46
Bulk density	Mg m^{-3}	1.19
Particle density	Mg m^{-3}	2.16
Maximum water holding capacity	%	40.64
Porosity	%	48.15
Acid phosphate	μg p-nitro phenol g^{-1} soilh^{-1}	272.08
Dehydrogenase	μg TTC g^{-1} soil 24 h^{-1}	750.02
Urease	μg g^{-1} soil h^{-1}	65.70

The field was thoroughly ploughed and cross harrowing was done to bring the soil to the fine tilth condition. Followed by that, clods were broken using clod crusher to make the soil loose and friable. Stubbles and weeds were cleared out manually and the field was leveled using a wooden plank. Farm Yard Manure was applied at a rate of @ 10 t ha^{-1} and mixed thoroughly with the soil. After this, ridges and furrows were laid. Cassava setts of 20–25 cm length were prepared and planted horizontally on 90 cm wide ridges, with a recommended plant to plant spacing of 90 cm by burying up to 10 cm in the soil.

Blanket recommendations of 100:50:100 kg N, P_2O_5 and K_2O ha^{-1} were usually followed for high-yielding cassava varieties (Nair et al., 2004). In this study, plots were given prescribed doses of nitrogen for each treatment and the full recommended dose of phosphorus and potassium. Half the doses of N and K, and the entire amount of P were applied at the time of planting and the remaining quantities of N and K were applied as top dressing four weeks after planting.

First irrigation was given immediately after planting. Proper soil moisture was maintained up to two to three weeks of planting till the full establishment of setts was noticed. Irrigation was given with sprinkler on alternative days to maintain proper soil moisture. Gap filling and thinning were done at 10 DAP (days after planting) in the planted crop for maintaining only one healthy stem cutting hill^{-1}. Four hand weedings were done at 30, 60, 90 and 120 DAP. The tubers were harvested 10 months after planting by digging up using a pickaxe.

From each treatment and replication, 5 plants in net plot area (16 plants) were chosen at random and observations of yield attributes and yield were taken. The number of tubers was counted for selected plants and average values were recorded as the number of tubers plant^{-1}. The length of the individual tuber from selected plants was measured from base to tip and average values were expressed in cm. The diameter of individual tubers from selected plants was measured at three points of tuber i.e., two ends and middle and average values were expressed in cm. The weight of tuber from each of the selected plants was recorded and average values were recorded as tuber yield plant^{-1} expressed in kg plant^{-1}. Plot-wise tuber yield was recorded in kg plot^{-1} and was converted to t ha^{-1} for tuber yield ha^{-1}. SPAD-502 m reading was recorded and chlorophyll a, chlorophyll b, total chlorophyll and leaf carotene content was calculated as per the procedure suggested by Uddling et al. (2017).

3. RESULTS AND DISCUSSION

3.1. Yield and yield attributes

Among the two varieties studied, significant differences were observed in the length of tuber and yield plant^{-1} with V_2 (Sree Reksha) recording higher tuber length (19.75 cm) and yield plant^{-1} (3.00 kg) than V_1 (Sree Pavithra). However, no significant difference was observed in diameter of tuber, number of tubers plant^{-1} and yield ha^{-1} among the tested varieties. Significantly higher values for yield and yield attributes were reported for N_4 [125% RD (recommended dose) of nitrogen-125 kg ha^{-1}], i.e super optimal dose of nitrogen, across the five different nitrogen application rates examined. Minimum values were recorded by N_0 (Control with no nitrogen application). Length of tuber recorded a maximum value of 25.48 cm in N_4 (125% of RD nitrogen-125 kg ha^{-1}), which is at par with N_3 (100% RD of nitrogen, 100 kg ha^{-1}) by 22.35 cm. The maximum value of the diameter of tuber (12.00 cm) was recorded by N_4 (125%RD of nitrogen- 125 kg ha^{-1}) followed by N_3 (100%RD of nitrogen- 100 kg ha^{-1}) with a value of 9.33 cm. Likewise, N_4 (125% RD of nitrogen- 125 kg ha^{-1}) had the most number of tubers plant^{-1} (3.55), followed by N_3 (100% RD of nitrogen-100 kg ha^{-1}) with value of 3.07. The highest tuber yields plant^{-1} (4.24 kg) and ha^{-1}(52.61 t) were recorded by N_4 (125% RD of nitrogen- 125 kg ha^{-1}) followed by N_3 (100% RD of nitrogen- 100 kg ha^{-1}) with tuber yields plant^{-1} and ha^{-1} of 3.90 kg and 47.73 t respectively. The findings were in agreement with those of Uwah et al. (2013) who reported that increasing nitrogen doses significantly boosted cassava yield and yield attributes. However, yield and yield attributes were not significantly influenced by the interaction between the varieties and nitrogen application rates (Table 2).

3.2. SPAD meter reading, leaf pigments and nitrogen content

SPAD meter reading showed significant differences among the varieties and different nitrogen application rates as well as in interaction between the varieties and nitrogen application rates. Among the varieties, V_2 (Sree Reksha) recorded higher SPAD meter reading of 45.44 units than V_1 (Sree Pavithra) which recorded a value of 37.49 SPAD units. Among the nitrogen application levels, super optimal dose of nitrogen i.e.,N_4 (125% RD of nitrogen, 125 kg ha^{-1}) recorded the highest SPAD meter reading (45.13 SPAD units) followed by N_3 (100% RD of nitrogen- 100 kg ha^{-1}) with a value of 42.09 SPAD units. Minimum SPAD meter readings were recorded by N_0 (Control with no nitrogen application) (Table 3).

While studying the interaction between the varieties and nitrogen application rates combination V_2N_4 (Sree Reksha+125% RD of nitrogen-125 kg ha^{-1}) recorded the highest SPAD meter reading (47.91 SPAD units) which is at par with the combinations V_2N_3 (Sree Reksha+100% RD of nitrogen-100 kg ha^{-1}) and V_2N_2 (Sree Reksha+50% RD of nitrogen-50 kg ha^{-1}) with 47.14 and 46.61 SPAD units respectively. Treatment combination V_1N_0 (Sree Pavithra+0% RD of nitrogen-0 kg ha^{-1}) recorded minimum reading of 35.10 SPAD units (Table 4).

Chlorophyll a, chlorophyll b, total chlorophyll and leaf carotene contents were found to be highest in treatment combination V_2N_4 (Sree Reksha+125% RD of nitrogen-125 kg ha^{-1}) and lowest in V_1N_0 (Sree Pavithra+0% RD of nitrogen-0 kg ha^{-1}). The highest leaf nitrogen content of 4.31% was recorded in treatment combination V_2N_4 (Sree Reksha+125%RD of nitrogen-125 kg ha^{-1}) while the lowest leaf nitrogen content

Table 2: Variation in yield and yield attributes of Cassava varieties on different nitrogen application rates

Treatments	Length of tuber (cm)	Diameter of tuber (cm)	No. of tubers plant^{-1}	Tuber yield plant^{-1} (kg)	Tuber yield (t ha^{-1})
Varieties (V)					
V_1	17.97	7.87	2.74	2.83	35.05
V_2	19.75	8.11	2.73	3.00	36.62
SEm±	0.55	0.33	0.07	0.04	0.65
CD (p=0.05)	1.65	NS	NS	0.12	NS
Nitrogen application rates (N)					
N_0	11.89	5.10	1.93	0.99	12.30
N_1	15.85	6.40	2.35	2.35	28.36
N_2	18.73	7.12	2.80	3.09	38.17
N_3	22.35	9.33	3.07	3.90	47.73
N_4	25.48	12.00	3.55	4.24	52.61
SEm±	0.87	0.51	0.11	0.07	1.03
CD (p=0.05)	2.61	1.54	0.33	0.20	3.07
Interaction (V×N)					
SEm±	1.23	0.73	0.15	0.09	1.451
CD (p=0.05)	NS	NS	NS	NS	NS

*N_0: Control with no nitrogen application, N_1: 25% RD of nitrogen (25 kg ha^{-1}), N_2: 50% RD of nitrogen (50 kg ha^{-1}), N_3: 100% RD of nitrogen (100 kg ha^{-1}), N_4:125% RD of nitrogen (125 kg ha^{-1}); *V_1: Sree Pavithra, V_2: Sree Reksha

of 3.16% was recorded by V_1N_0 (Sree Pavithra+0% RD of nitrogen-0 kg ha^{-1}). In essence, as the rate of nitrogen application was increased, higher levels of chlorophyll content were found in cassava (Figure 1). This is in line with the findings of Uwah et al. (2013), who reported that nitrogen boosts chlorophyll in leaves thereby improving the plant's photosynthetic potential, plays a role in protein synthesis and contributes to higher yield in plants.

3.3. *Phosphorous and potash uptake*

The phosphorus content of the stem and tuber differed significantly between the two varieties evaluated, however, the phosphorous content of the leaf does not differ significantly. The phosphorous content in stem was significantly higher in V_2 (Sree Reksha) (0.53%) while phosphorous content in tuber was higher in V_1 (Sree Pavithra) (0.19%). However, the potash content in stem and leaf differed significantly and no significant difference was observed in the potash content in tuber among the two varieties studied. Significantly higher potash content in both stem (1.21%) and leaf (1.50%) were recorded by V_2 (Sree Reksha). Treatment with super optimal dose of nitrogen i.e N_4 (125%RD of nitrogen-125 kg ha^{-1}) recorded significantly higher values for phosphorous content in stem (0.53%) and leaf (0.47%),potash content in stem (1.34%), leaf (1.69%) and tuber (1.04%). The results are aligned with reports of Aulakh and Malhi (2005) who stated that increased N supply enhances K concentration and absorption in conditions of high K availability. However, phosphorous content in tuber did not

Table 3: Effect of varieties and nitrogen application rates on SPAD meter reading of Cassava leaves

Treatments	SPAD meter reading (SPAD units)
Varieties (V)	
V_1	37.49
V_2	45.44
SEm±	0.26
CD (p=0.05)	0.78
Nitrogen application rates (N)	
N_0	38.23
N_1	40.08
N_2	41.79
N_3	42.09
N_4	45.13
SEm±	0.41
CD (p=0.05)	1.24
Interaction (V×N)	
SEm±	0.58
CD (p=0.05)	1.75

*N_0: Control with no nitrogen application, N_1: 25% RD of nitrogen (25 kg ha^{-1}), N_2: 50% RD of nitrogen (50 kg ha^{-1}), N_3: 100% RD of nitrogen (100 kg ha^{-1}), N_4: 125% RD of nitrogen (125 kg ha^{-1}); *V_1: Sree Pavithra, V_2: Sree Reksha

Table 4: SPAD meter reading as influenced by the interaction of varieties and nitrogen application rates (V×N)

Treatments	N_0	N_1	N_2	N_3	N_4	Mean
Varieties (V)						
V_1	35.10	36.01	36.96	37.04	42.34	37.49
V_2	41.37	44.15	46.61	47.14	47.91	45.44
Mean	38.23	40.08	41.78	42.09	45.13	
SEm±	0.58					
CD (p=0.05)	1.75					

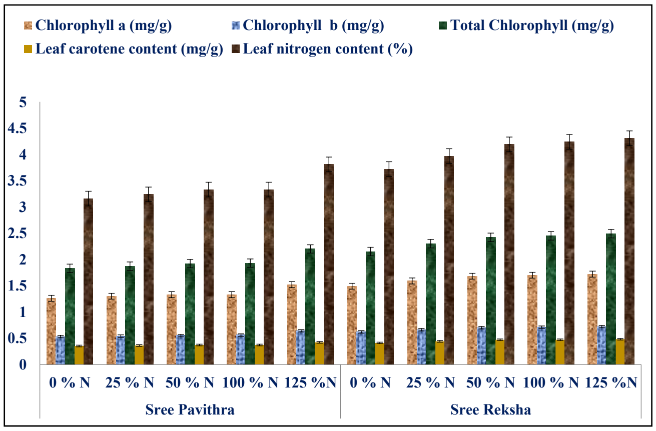

Figure 1: Chlorophyll a, chlorophyll b, total chlorophyll, carotene and nitrogen contents of Cassava leaves

show a significant difference among the different nitrogen application rates studied (Table 5).

In interaction studies of varieties and nitrogen application rates, among the treatment combinations, no significant differences were observed in the phosphorous content in the stem, leaf and tuber and potash content in the stem (Table 6). However,

Table 5: Phosphorus and potash content on Cassava varieties as influenced by different nitrogen application rates

Treatments	Phosphorous (%)			Potassium (%)		
	Stem	Leaf	Tuber	Stem	Leaf	Tuber
Varieties (V)						
V_1	0.36	0.45	0.19	0.63	1.33	0.80
V_2	0.53	0.41	0.15	1.21	1.50	0.84
SEm±	0.01	0.01	0.01	0.03	0.01	0.02
CD (p=0.05)	0.03	NS	0.04	0.08	0.02	NS
Nitrogen application rates (N)						
N_0	0.37	0.39	0.16	0.59	1.08	0.60
N_1	0.43	0.40	0.16	0.70	1.29	0.75
N_2	0.45	0.45	0.17	0.95	1.46	0.83
N_3	0.47	0.45	0.17	1.03	1.56	0.89
N_4	0.53	0.47	0.19	1.34	1.69	1.04
SEm±	0.02	0.02	0.02	0.04	0.01	0.03
CD (p=0.05)	0.05	0.06	NS	0.13	0.03	0.09
Interaction (V×N)						
SEm±	0.02	0.03	0.03	0.06	0.02	0.04
CD (p=0.05)	NS	NS	NS	NS	0.05	0.12

*N_0: Control with no nitrogen application, N_1: 25% RD of nitrogen (25 kg ha^{-1}), N_2: 50% RD of nitrogen (50 kg ha^{-1}), N_3: 100% RD of nitrogen (100 kg ha^{-1}), N_4: 125% RD of nitrogen (125 kg ha^{-1}); *V_1: Sree Pavithra, V_2: Sree Reksha

Table 6: Leaf potash content as influenced by the interaction of varieties and nitrogen application rates (V×N)

Treatments	N_0	N_1	N_2	N_3	N_4	Mean
Varieties (V)						
V_1	0.90	1.28	1.43	1.48	1.56	1.33
V_2	1.26	1.3	1.48	1.64	1.82	1.50
Mean	1.08	1.29	1.46	1.56	1.69	
SEm±	0.02					
CD (p=0.05)	0.05					

potash content in leaf and tuber differ significantly. Treatment combination V_2N_4 (Sree Reksha+125%RD of nitrogen-125 kg ha^{-1}) had the highest potash content in leaf (1.82%) while treatment combination V_1N_4 (Sree Pavithra+125%RD of nitrogen-125 kg ha^{-1}) had the highest potash content in tuber (0.97%) (Table 6 and 7).

Table 7: Tuber potash content as influenced by the interaction of varieties and nitrogen application rates (V×N)

Treatments	N_0	N_1	N_2	N_3	N_4	Mean
Varieties (V)						
V_1	0.55	0.68	0.77	0.89	1.10	0.80
V_2	0.64	0.82	0.88	0.89	0.97	0.84
Mean	0.60	0.75	0.83	0.89	1.04	
SEm±	0.04					
CD (p=0.05)	0.12					

3.4. Dry matter production

Dry matter content in stem, leaf, and tuber differed significantly between the two varieties evaluated with V_1 (Sree Pavithra) recording higher dry matter content in stem (45.39%) and leaf (31.37%), while V_2 (Sree Reksha) had higher dry matter content in tubers (43.63%). Treatment with super optimal dose of nitrogen i.e N_4 (125% RD of nitrogen-125 kg ha^{-1}) recorded higher dry matter content in stem (49.28%), leaf (32.75%) and (47.66%) in comparison to other treatments. Dry matter content in leaf was on par in the treatments N_4 (125% RD of nitrogen-125 kg ha^{-1}) and N_3 (100% RD of nitrogen-100 kg ha^{-1}) with 32.75% and 31.16% respectively (Table 8).

The dry matter content of stem and tuber differed significantly in interaction trials of varieties and nitrogen application rates, although the dry matter content of leaf did not effected significantly. Treatment combination V_1N_4 (Sree Pavithra+125% RD of nitrogen-125 kg ha^{-1}) had the highest dry matter content in stem (53.96%) while V_2N_4 (Sree Reksha+125% RD of nitrogen-125 kg ha^{-1}) had the highest dry matter content in tubers (Table 9 and 10).

Table 8: Effect of different treatments on dry matter content on Cassava varieties

Treatments	Dry matter content (%)		
	Stem	Leaf	Tuber
Varieties (V)			
V_1	45.39	31.37	40.50
V_2	39.37	28.80	43.63
SEm±	0.30	0.45	0.20
CD (p=0.05)	0.90	1.33	0.60
Nitrogen application rates (N)			
N_0	31.14	26.87	36.67
N_1	39.35	29.47	40.74
N_2	45.63	30.18	41.89
N_3	46.52	31.16	43.36
N_4	49.28	32.75	47.66
SEm±	0.48	0.70	0.32
CD (p=0.05)	1.43	2.11	0.95
Interaction (V×N)			
SEm±	0.67	0.99	0.45
CD (p=0.05)	2.02	NS	1.34

Table 9: Dry matter content of stem as influenced by the interaction of varieties and nitrogen application rates (V×N)

Treat-ments	N_0	N_1	N_2	N_3	N_4	Mean
Varieties (V)						
V_1	27.79	40.23	52.44	52.55	53.96	45.39
V_2	34.49	38.48	38.81	40.49	44.60	39.37
Mean	31.14	39.35	45.63	46.52	49.28	
SEm±	0.67					
CD (p=0.05)	2.02					

Table 10: Dry matter content of tuber as influenced by the interaction of varieties and nitrogen application rates (V×N)

Treat-ments	N_0	N_1	N_2	N_3	N_4	Mean
Varieties (V)						
V_1	33.53	39.49	40.31	42.26	46.89	40.50
V_2	39.80	42.00	43.47	44.45	48.44	43.63
Mean	36.67	40.74	41.89	43.36	47.66	
SEm±	0.45					
CD (p=0.05)	1.34					

4. CONCLUSION

Applying super optimal dose of nitrogen (125% RD of nitrogen, 125 kg ha^{-1}) had a beneficial impact on the yield and yield attributes of Cassava. The two varieties evaluated in this trial performed equally well, although Sree Reksha slightly outperformed Sree Pavithra in terms of yield and yield attributes. Super optimal dose of nitrogen (125 kg ha^{-1}) is to be recommended for augmenting Cassava yield and yield attributes.

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