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Effect of plant growth regulators and nutrient levels on yield attributes and yield of pearl millet

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Abstract
A field experiment was carried out to study effect of plant growth regulators and nutrient levels on yield attributes and yield of pearl millet during *rabi* 2016 at TNAU, Coimbatore, Tamil Nadu, India. Ten treatments with nutrient levels and plant growth regulators were imposed with three replications using RBD. The application of 125 % RDF + foliar application of NAA @ 40 ppm at 20 and 40 DAS (T_7) had significant influence on yield attributes of pearl millet *viz.,* productive tillers plant^{-1}, earhead length and earhead girth. Application of 125 % RDF + foliar application of NAA @ 40 ppm at 20 and 40 DAS (T_7) significantly influenced the grain yield and it was at par with the 100 % RDF + foliar application of NAA @ 40 ppm at 20 and 40 DAS (T_8). Application of 125 % RDF + foliar application of NAA @ 40 ppm at 20 and 40 DAS (T_7) recorded 94.9 and 19.7 per cent increase in yield over control (T_{10}) and 100 % RDF (T_2), respectively and also 100 % RDF + foliar application of NAA @ 40 ppm at 20 and 40 DAS (T_8) recorded 92.9 and 18.5 per cent increase over control (T_{10}) and 100 % RDF (T_2), respectively. Stover yield increased with the application of 125 % RDF + foliar application of NAA @ 40 ppm at 20 and 40 DAS (T_7) but at par with the 100 % RDF + foliar application of NAA @ 40 ppm at 20 and 40 DAS (T_8). Application of 125 % RDF + foliar application of NAA @ 40 ppm at 20 and 40 DAS (T_7) recorded 79.4 and 22.2 per cent over the control (T_{10}) and 100 % RDF (T_2), respectively.

Keywords: Growth regulators, NAA, chloromequat chloride, pearl millet

Introduction
Pearl millet **(***Pennisetum glaucum* (L) is the staple cereal of arid and semi-arid drier regions of the country. It is the most widely cultivated cereal in India after rice and wheat. India is the largest Pearl millet growing country contributing 42 per cent of production in the world. In India, pearl millet is pre-dominantly cultivated as a rainfed crop in diverse soils, climatic condition and indispensable arid zone. Pearl millet **(***Pennisetum glaucum* (L) is the staple cereal of arid and semi-arid drier regions of the country. In India pearl millet was cultivated in 7.128 million hectares with 8.06 million tonnes production of and productivity of 1132 kg/ha during 2015-16 (Season and Crop Report 2015-16). The major pearl millet producing states in India are Rajasthan, Maharashtra, Gujarat, Uttar Pradesh and Haryana. Land, which is on mercy of rainfall, is not only thirsty but also hungry. The estimated nutrient removal by all dryland crops is to the tune of 7.4 million tonnes (excluding secondary and micro nutrients). Approximately drylands receive 10 per cent of total nutrients use in the country, which constitutes about 1.4 million tonnes. There remains a net negative balance of about 6.0 million tonnes (Lakshmi, 2001) [12].

The productivity of pearl millet is very low in India mainly due to poor plant stand and less use of fertilizers. Pearl millet removes 72 kg N, P_2O_5 and K_2O ha^{-1} annum^{-1}, whereas only 10-20 kg of these nutrient are being supplied through fertilizers. Therefore, there is need to improve fertility management along with optimum plant density of current hybrids for sustainable production and productivity. The plant growth regulators (PGRs) have potential for increasing crop productivity under environmental stress. Growth regulators are chemical substances which can alter the growth and developmental processes (Espindula *et al*., 2009) [8] leading to increased yield, improved grain quality or facilitated harvesting.

Pearl millet responds well to fertilizer application and the increase due to each successive level of fertilizer applied was significant for earhead length, earhead girth and test weight. The positive effect of fertilizer application on yield attributing characters of pearl millet seems to be due to cumulative effect on growth and vigour of plants.

By virtue of increased supply of metabolites, there might have been significant improvement in growth characters with increasing fertilizer application. Increased growth components owing to increased fertilizer levels might have provided stability in higher supply of photo-synthates towards the sink (grain ear^{-1}). Plant growth regulators and nutrient levels had significant influence on, yield attributes, grain and stover yield. The present research was designed to study the performance of nutrients and plant growth regulators in pearl millet.

Material and methods

Field experiment was conducted at Tamil Nadu Agricultural University, Coimbatore during Rabi 2016 to study the effect of nutrient levels and plant growth regulators on growth and yield of pearl millet (Cumbu hybrid CO 9).The farm is situated at 110 North latitude and 770 E longitude and at an altitude of 426.7 m above mean sea level. The soil of the experimental site was sandy clay loam in texture with low in available nitrogen, medium in available phosphorus and high in available potassium contents. During the cropping period, the mean of maximum and minimum temperature was 32.2 and 22.0 ^{0}C respectively. The total rainfall received during the cropping period was 129 mm in 5 rainy days. The mean of relative humidity was 86.6 per cent and 53.6 per cent during forenoon and afternoon, respectively. The mean of sunshine hours was 6.4 hrs day^{-1}.

The mean of evaporation prevailed during the cropping period was 5.4 mm day^{-1} and the wind velocity was 6.5 km hour^{-1}. The pearl millet hybrid of CO-9 was used for the experiment with 5 kg ha^{-1} seed rate. The soil of the experimental field was in slightly alkaline (8.07), normal in EC (0.86 dsm^{-1}), sandy clay loam in texture, low in OC (0.59 %), low in available nitrogen (260.0 kg ha^{-1}), medium in available P_2O_5 (20.4 kg ha^{-1}) and high in available K_2O (694.2 kg ha^{-1}). The nitrogen application was done in two splits, 50 % of N, full dose of P_2O_5 and K_2O were applied as a basal and remaining 50 % N at 30 days after sowing of pearl millet. Plants from each treatment in the plot were selected at random and tagged for taking the observation *viz* like number of tillers and productive tillers. Five earheads were selected at random and the length of earheads was measured from the base to the tip of the earhead and average earhead length was expressed in centimeters (cm). The number of earheads from five randomly selected plants was harvested, dried and diameter was taken with Vernier Caliper and averaged out and expressed in cm per earhead. Earheads of the net plot were harvested separately. The earheads were sun dried, shelled, cleaned and grain yield was recorded for individual treatment after drying to 14 per cent moisture and expressed in kg ha^{-1}. The stover yield in the net plot area were cut close to the ground level and after drying, weight of stover from each treatment was recorded and expressed in kg ha^{-1}.The experiment was laid out in randomized block design with three replications and ten treatments viz. T_1 - 125% RDF*, T_2 - 100 % RDF*, T_3 - 75% RDF*, T_4 - 125% RDF* + Foliar application of chlormequat chloride @ 250 ppm at 20 and 40 DAS, T_5 - 100 % RDF* + Foliar application of chlormequat chloride @ 250 ppm at20 and 40 DAS, T_6 - 75% RDF* + Foliar application of chlormequat chloride @ 250 ppm at 20 and 40 DAS, T_7 - 125% RDF* + Foliar application of NAA @ 40 ppm at 20 and 40 DAS, T_8 - 100 % RDF* + Foliar application of NAA @ 40 ppm at 20 and 40 DAS, T_9 - 75% RDF* + Foliar application of NAA @ 40 ppm at 20 and 40 DAS and T_{10} – Control. The data collected were analyzed statistically following the procedure given by Panse and Sukhatme. Wherever the treatmental differences were significant, critical differences were worked out at five per cent probability level. Treatment differences that were not significant are denoted as NS.

Results and Discussion

Total number of tillers and productive tillers

Among the treatments, application of 125 % RDF + foliar application NAA @ 40 ppm at 20 and 40 DAS (T_7) produced higher total number of tillers and number of productive tillers and it was on par with application of 125 % RDF + foliar application of Chloromequat chloride @ 250 ppm at 20 and 40 DAS (T_4) and 100 % RDF + foliar application of NAA @ 40 ppm at 20 and 40 DAS (T_8). Among the treatments, T_7 produced higher total number tillers and number of productive tillers plant^{-1} due to total number of tillers increased significantly with the application of phosphorus could be due to increase in soil micro-organism and also due to better moisture and nutrient availability (Singh and Ram, 2001) [26]. The major impact of cycocel on grain yield is mediated *via* initiation of more tillers per plant resulting in a greater number of grains. The work of Emam and Moaied (2000) [7] on winter barley as well as that of Shekoofa and Emam (2008) on winter wheat confirmed that the increased grain yield was the result of higher grain number and significant inhibition on the growth of unproductive tiller of rice plants with NAA application and the elimination of unproductive tillers promote growth of productive tillers at an appropriate concentration (Liu *et al.*, 2012) [13]. Experiment with NAA and nutrient application in field conditions observed that productive tillers increased significantly by the application of nutrients and NAA (Basuchaudhuri 2016) [6].

Earhead length and girth

The different nutrient levels and plant growth regulators had significant influence on the earhead length and girth in pearl millet. Application of 125 % RDF + foliar application of NAA @ 40 ppm at 20 and 40 DAS (T_7) recorded significantly lengthier earhead (29.30 cm) and more earhead girth (13.01cm) than other treatments and followed by the 100 % RDF + foliar application of NAA @ 40 ppm at 20 and 40 DAS (T_8) and application 125 % RDF (T_1) treatments. Due to attribute to overall improvement in vigour and crop growth. The high yield attributes are the result of higher nutrient availability which resulted in better growth and more translocation of photosynthates from source to sink (Priyadarshani *et al.*, 2012) [21]. Generally, the trend indicated consistent increment in earhead length and girth with increment of nitrogen fertilizer rate from control treatment to 125 % RDF ha^{-1}. The increase in earhead length and girth at higher nitrogen levels could be due to lower competition for nutrient that allowed the plants to accumulate more biomass with higher capacity to convert more photosynthesis into sink resulting in longer earhead and girth per plant and increase in nitrogen levels also increased ear length and girth (Ayman and Samier, 2015) [5]. Among the plant growth regulators, recorded maximum pod length observed by NAA whereas minimum pod length was observed with cycocel. The increase in pod length with the application of NAA might be due to rapid cell division and increased elongation of individual cell. Similar results were reported by Kokare *et al.* (2006) [10] in okra.

Grain yield

There was significant influence recorded on pearl millet grain yield due to application of different nutrient levels and plant growth regulators. Among the treatments application of 125 % RDF + foliar application of NAA @ 40 ppm at 20 and 40 DAS (T_7) recorded more grain yield (3310 kg ha^{-1}) and it was on par with 100 % RDF + foliar application of NAA @ 40 ppm at 20 and 40 DAS (3276 kg ha^{-1}) than other treatments. Application of 100 % RDF + foliar application of NAA @ 40 ppm at 20 and 40 at DAS (T_8) and 100 % RDF + foliar application of chloromequat chloride @ 250 ppm at 20 and 40 DAS (T_5) enhanced the grain yield significantly compared to 100 % RDF (T_2). The control (T_{10}) had significantly lower grain yield (1698 kg/ha) than all tested treatments.

The efficiency of grain filling is associated with photosynthetic efficiency and translocation of photosynthates. This was attributed to mobilization of food materials to reproductive sink for perfect seed filling process by increasing hydrolyzing and oxidative enzyme activities**.** Among the treatments, application of 125 % RDF + foliar application of NAA @ 40 ppm at 20 and 40 DAS (T_7) recorded more grain and stover yield but it was at par with 100 % RDF + foliar application of NAA @ 40 ppm at 20 and 40 DAS (T_8) than other treatments. The increase in grain and straw yields with enhanced nutrient application could be ascribed to increase in the activity of cytokinin in plant which leads to the increased cell division and elongation thereby results in better plant growth, drymatter production and higher photosynthesis (Prasad *et al.*, 2016) [20].

Naphthalene acetic acid (NAA), in combination with nitrogen fertilizer can be a good potential tool for increasing the growth and yield of the crop. At appropriate concentration, NAA can influence the growth, development and other physiological and biochemical processes of plants (Iqbal *et al*., 2009) [9]. The yield attributes and yield of pearl millet were significantly influenced by nutrient and plant growth regulators application (Nigade *et al.*, 2011) [16]. The grain and stover yields per plant and hectare were significantly increased by different concentrations of NAA treatments and also in combination with different N levels over the control. The grain yield recorded maximum at 40 ppm NAA in combination with nitrogenous fertilizer application. Similar increase in grain yield was reported by Alam *et al.* (2002) [3] and Jahan and Adam (2013). Increased grain stover yield of other cereal plants due to different nutrient levels and NAA application had also been reported by different investigators on different plants viz. maize (Akter, 2010) [1], sorghum (Tulsa-Ram *et al.*, 1997) [30] and baby corn (Muthukumar *et al.*, 2005) [15]. According to Rhodes and Ashworth (1952) [22], the metabolism of auxins and growth promoters generates the energy-rich phosphate and precursors of metabolic processes, which may be the factors in the initiation of enhanced growth processes. The increased growth and delayed senescence in turn, favoured increase in yield as most of the assimilates were translocated from the source to the sink under a stimulated environment.

The significant increase in grain and stover yield of pearl millet was largely a function of improved growth and the consequent increase in different yield attributes. This favourable effect might be owing to the fact that P is well known for its role as ‘Energy currency’ and plays a key role in development and energy transformation in various vitally important metabolic processes in the plant (Sammauria and Yadav, 2008) [23].

The response of pearl millet to applied nitrogen might be ascribed to the favourable effect of nitrogen application on yield and yield-attributing characters.

This might be due to the fact that nitrogen lead to higher availability of nutrient that promoted growth and development and ultimately resulting in increasing yield attributes and yield (Singh and Agarwal, 2004) [27].

The maize stover yield obtained with 200 kg N was 13.67 per cent higher than 100 kg N/ha. The higher biomass, grain and stover yield obtained with 200 kg N/ha was attributed to higher value of different yield attributing parameters (Singh *et al.*, 2015) [28].

Cob yield increased due to increased mobilization of reserve food materials to developing sink through increase in hydrolyzing and oxidizing enzyme activities (Velu, 2002) [31], continuous and gradual supply of nitrogen to the plants to maintain greenness of leaves for longer period which in turn helped in greater dry matter accumulation and contributed much to the developing sink and thereby increased the green cob yield (Muthukumar *et al.*, 2005) [15]. Increase in fodder yield due to NAA spray might be due to increase in plant height, leaf area index and total biomass which might be due to increased cell division, cell enlargement and elongation. Similar findings were also reported in black gram (Lakshmamma and Rao, 1996) [11] and Coriander (Pareek *et al.*, 2000) [19]. The higher yield with N application at earlier growth stages may be due to the greater number of spikes produced per meter. Harvest index tended to increase with increased application of nitrogen (Taalab 2015) [29].

Stover yield

The stover yield was significantly influenced by the application of nutrient levels and plant growth regulators. Among different treatments, application of 125 % + foliar application of NAA @ 40 ppm at 20 and 40 DAS (T_7). It was at par with 100 % RDF + foliar application of NAA @ 40 ppm at 20 and 40 DAS (T_8) and followed by application of 125 % RDF + foliar application of chloromequat chloride @ 250 ppm at 20 and 40 DAS (T_4). The control (T_{10}) recorded least value of stover yield (3561 kg/ha) compared to all other treatments. The increase in yield by the application of NAA might be attributed to its unique role in delaying senescence process, hastening root and shoot growth, higher fertility rate of reproductive organ due to creation of favorable balance of hormones and setting more fruits. These results were in tune with the results reported by Arora *et al.* (1994) [4] in long melon, Alagukannan and Vijaykumar (1999) [2] in fenugreek, Medhi (2000) [14] in french bean, Pandey *et al*. (2004) [17] in garden pea and Kokare *et al.*, (2006) [10] in okra.

Conclusion

Application of 125 % RDF + foliar application of NAA @ 40 ppm at 20 and 40 DAS recorded higher grain and stover yields, whereas 100 % RDF + foliar application of NAA @ 40 ppm at 20 and 40 DAS realized higher monetary returns and B: C.

Table 1: Effect of plant growth regulators and nutrient levels on total number of tillers and productive tillers $plant^{-1}$ of pearl millet

Treatment	Total No, of tillers $plant^{-1}$	No. of productive tillers $plant^{-1}$
T_1- 125 % RDF*	5.16	3.52
T_2- 100 % RDF*	4.60	3.20
T_3- 75 % RDF*	4.50	3.07

T_4- 125 % RDF* + foliar application of Chloromequat chloride @ 250 ppm at 20 and 40 DAS	6.00	4.16
T_5- 100 % RDF* + foliar application of Chloromequat chloride @ 250 ppm at 20 and 40 DAS	5.70	3.91
T_6- 75 % RDF* + foliar application of Chloromequat chloride @ 250 ppm at 20 and 40 DAS	4.80	3.26
T_7- 125 % RDF* + foliar application of NAA @ 40 ppm at 20 and 40 DAS	5.90	4.18
T_8- 100 % RDF* + foliar application of NAA @ 40 ppm at 20 and 40 DAS	5.60	3.97
T_9- 75 % RDF* + foliar application of NAA @ 40 ppm at 20 and 40 DAS	5.00	3.46
T_{10}- Control	4.50	2.53
S. Ed	0.24	0.22
C.D at 5 %	0.52	0.47

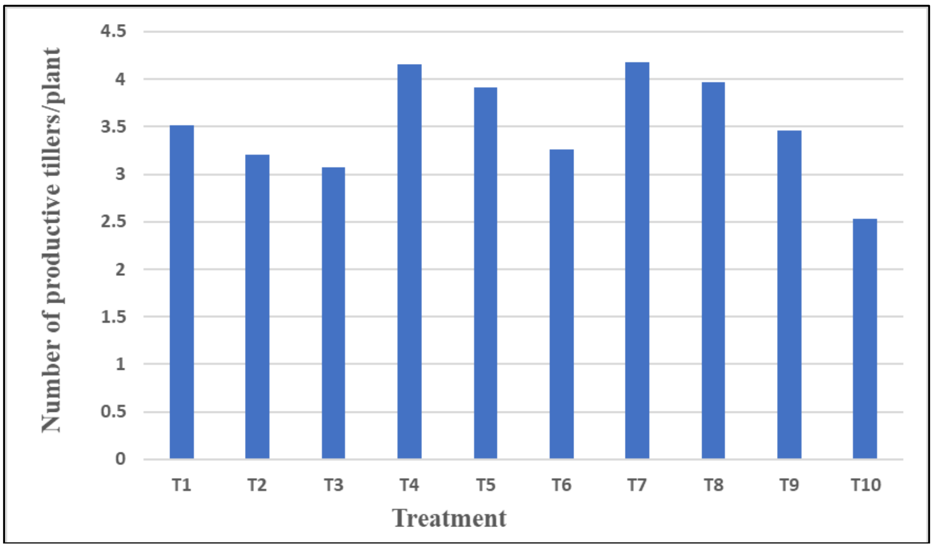

Fig 1: Effect of nutrient level and plant growth regulators on number of productive tillers plant^{-1}.

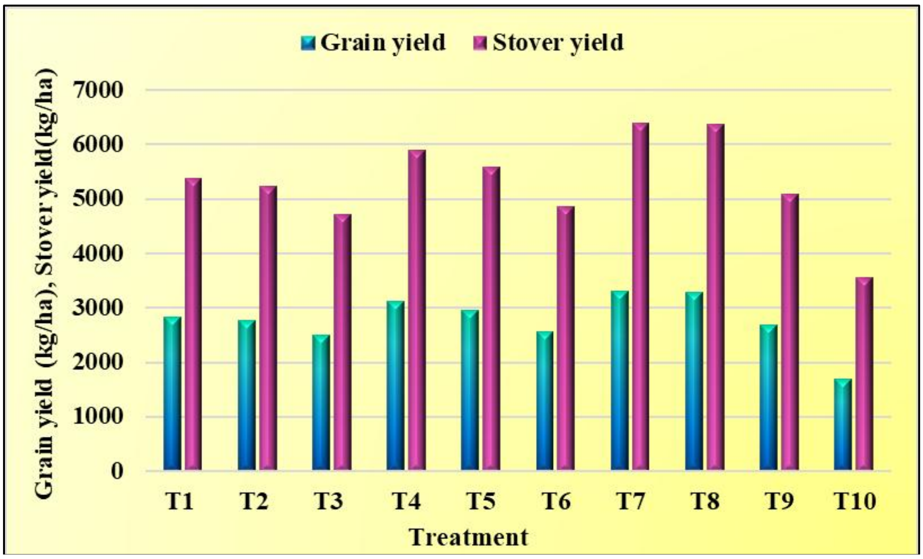

Fig 2: Effect of nutrient levels and plant growth regulators on grain and stover yield of pearl millet

Table 2: Effect of nutrient levels and plant growth regulators on ear head length, girth (cm) and test weight (g) of pearl millet

Treatment	Earhead	
	Length (cm)	Girth (cm)
T_1- 125 % RDF*	26.36	12.09
T_2- 100 % RDF*	22.10	10.23
T_3- 75 % RDF*	20.80	9.17
T_4- 125 % RDF* + foliar application of Chloromequat chloride @ 250 ppm at 20 and 40 DAS	25.67	11.65
T_5- 100 % RDF* + foliar application of Chloromequat chloride @ 250 ppm at 20 and 40 DAS	23.50	9.95
T_6- 75 % RDF* + foliar application of Chloromequat chloride @ 250 ppm at 20 and 40 DAS	20.00	9.09
T_7- 125 % RDF* + foliar application of NAA @ 40 ppm at 20 and 40 DAS	29.30	13.05
T_8- 100 % RDF* + foliar application of NAA @ 40 ppm at 20 and 40 DAS	26.50	11.26
T_9- 75 % RDF* + foliar application of NAA @ 40 ppm at 20 and 40 DAS	21.50	9.37
T_{10}- Control	17.60	8.33
S. Ed	1.11	0.49
C.D at 5 %	2.35	1.04

Table 3: Effect of nutrient levels and plant growth regulators on grain and stover yield (kg ha^{-1}) of pearl millet

Treatment	Yield (kg ha^{-1})	
	Grain	Stover
T_1- 125 % RDF*	2838	5370
T_2- 100 % RDF*	2763	5227
T_3- 75 % RDF*	2498	4722
T_4- 125 % RDF* + foliar application of Chloromequat chloride @ 250 ppm at 20 and 40 DAS	3121	5902
T_5- 100 % RDF* + foliar application of Chloromequat chloride @ 250 ppm at 20 and 40 DAS	2951	5581
T_6- 75 % RDF* + foliar application of Chloromequat chloride @ 250 ppm at 20 and 40 DAS	2568	4856
T_7- 125 % RDF* + foliar application of NAA @ 40 ppm at 20 and 40 DAS	3310	6390
T_8- 100 % RDF* + foliar application of NAA @ 40 ppm at 20 and 40 DAS	3276	6370
T_9- 75 % RDF* + foliar application of NAA @ 40 ppm at 20 and 40 DAS	2694	5098
T_{10}- Control	1698	3561
S. Ed	133	255
C.D at 5 %	281	537

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