Range Management and Agroforestry 45 (2) : 335-341, 2024
ISSN 0971-2070 (Print); 2249-5231 (Online)
https://doi.org/10.59515/rma.2024.v45.i2.20

Research article

Effect of spacing and nitrogen management on productivity and quality of fodder oat in high ranges of Kerala

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Received: 19th September, 2023 Accepted: 06th August, 2024

Abstract

A study was undertaken during winter seasons of 2021-2022 to standardize spacing and nitrogen levels to realize optimum productivity of fodder oat. Treatments were laid out in factorial RBD with 9 treatments in 3 replications. Treatments consisted of three levels, each of two factors *viz.,* row spacing at 15, 25 and 35 cm and nitrogen levels 60, 90 and 120 kg ha^{-1}, respectively. The results revealed that wider row spacing of 35 cm recorded higher tiller count (9.22 tillers per hill), whereas higher green fodder, dry matter yields (26.58 and 5.32 t ha^{-1}) and NPK uptake (104.81, 24.47 and 88.32 kg ha^{-1}, respectively) was recorded in narrow row spacing of 15 cm. Nitrogen level of 120 kg N ha^{-1} recorded the highest GFY (27.69 t ha^{-1}), DMY (5.54 t ha^{-1}) chlorophyll (3.54 mg g^{-1}) and crude protein content (12.54%). It also improved leaf area index, leaf area duration and specific leaf area. The interaction of spacing and nitrogen was significant in some parameters. Spacing of 35 cm with 120 kg N ha^{-1} recorded the tallest plant (111.19 cm) and a greater number of tillers (9.29 hill^{-1}). In case of GFY and DFY spacing of 15 cm with 120 kg N ha^{-1} recorded the highest yields of GFY (30.14 t ha^{-1}) and DMY (6.03 tha^{-1}), uptake of nitrogen (120.97 kg ha^{-1}), phosphorus (27.91 kg ha^{-1}) and potassium (100.46 kg ha^{-1}).

Keywords: Crude protein, Fodder productivity, Nitrogen management, Planting geometry

Introduction

In India, livestock has been an integral component of farmer's economy which contributes about 4.11 percent to total GDP and possess 15 percent of world's livestock population (DAHDF, 2012). The success of animal husbandry and dairy farming largely depends on regular supply of good quality fodder in sufficient quantities. Unfortunately, there is shortage of green fodder due to less acreage under fodder crops and more emphasis on food grain production (Singh *et al.,* 2022) that drastically affects the productivity of animals in comparison with other countries (Mahanta *et al*., 2020). The mismatch in demand and supply of fodders requires urgent attention to develop suitable strategies to increase the productivity and bridge this gap in this region.

Oat (*Avena sativa* L.) is an important *Rabi* cereal fodder crop in India. It is the most important winter cereal fodder which is highly palatable, rich source of energy, protein, vitamin B_1, phosphorus, iron and other minerals. Its whole-plant is used for grazing, green forage, silage, hay, or as grain. It is often used in mixture with legumes for forage production. The crop requires a long and cool season for its growth and can be grown successfully in plains and hilly areas in the country.

In fodder crops, nitrogenous fertilizer is the most important input for production as the maximum vegetative growth is desired within a short period of time. Nitrogen plays an essential role in photosynthesis and is an indispensable part of protein. Oat responds well to nitrogen application, which produces more tonnage per unit area per unit time under favourable environmental conditions. However, excess application of nitrogen to oat under certain environmental conditions may cause excess nitrate accumulation in plant, which may be toxic to ruminants. Row spacing is an important agronomic approach, which severely affects the plant growth, development as well as productivity of fodder oat through its influence on nutrient, moisture and sunlight availability, as crop geometry is linked with the fertility status and competition for resources (Irfan *et al.*, 2016). It also affects crop productivity by altering crop canopy architecture, photosynthetic and assimilation efficiency of leaves and source-sink relationship of crop plants (Samani *et al.*, 1999). Higher plant density increases inter plant competition, whereas resources may remain underutilized under sparse spacing. Thus there is a considerable scope for enhancing growth, yield, quality and physiological characters of fodder oat by adjusting optimum spacing.

The high range zone in Kerala faces green fodder scarcity during winter months and farmers feed their animals with dry stalks of *Kharif* crops and grasses. Oat being a cool season crop comes up well in Wayanad district of Kerala during winter months. Since meagre scientific data and studies are available on fodder oat for high ranges of Kerala, this study was planned to find effect of spacing and nitrogen level on fodder oat production in Wayanad Eastern Plateau (AEU 20) of Kerala.

Materials and Methods

Experimental site and crop management: The experiment was laid out at Instructional Farm, RARS, Wayanad, Kerala during November 2021 to February 2022. The site was located at an altitude of 974 m above MSL and lies between 11°27′ and 15°58′ N latitude, and 75°47′ and 70°27′ E longitude. The soil of the experimental site was sandy loam in texture (sand 48.3%, silt 33.6% and clay 18.1%), strongly acidic (5.18) in reaction, low in organic carbon (0.49%), normal in electrical conductivity (0.2 dS m^{-1}), medium in available nitrogen (283.34 kg ha^{-1}), high in available phosphorus (26.83 kg ha^{-1}) and medium in available potassium (179.2 kg ha^{-1}). The experiment was laid out in factorial RBD with 9 treatments, each with three replications. Treatments consisted of two factors *viz.*, row spacing (S) and nitrogen levels (N) at three levels each *viz.*, S_1 (15), S_2 (25) and S_3 (35 cm); and N_1 (60), N_2 (90) and N_3 (120 kg ha^{-1}), respectively. Fodder oat variety, Kent was used in the study.

The experimental field was ploughed to fine tilth. Solid row sowing of seeds was done at a spacing *viz.*, 15 cm, 25 cm and 35 cm. To ensure uniform plant population, gap filling was done two weeks after planting. FYM @ 15 t ha^{-1} was uniformly applied and thoroughly incorporated in all plots, 20 days before final land preparation. Entire dose of phosphorus and potassium were applied as basal. Nitrogen doses were calculated as per treatments and applied in two splits, 60% as basal + 40% at 40 days after sowing to respective plots. First irrigation was given 5 days after sowing and subsequent irrigations were given as per the requirement of crop to maintain sufficient moisture in soil. Harvesting was done at 76 days after sowing at 50% flowering stage.

Growth and yield attributes: Plant height was measured from base of the plant to tip of the longest leaf for three plants. The mean heights were worked out and expressed in centimeters (cm). Tillers were counted from the observational plants (three in each plot) and mean was expressed as number of tillers $hill^{-1}$ at harvest. Crop was cut just above the ground and then bundled and data recorded. Fresh weight of the plants in net plot was recorded after the harvest and total green fodder yield (GFY) was expressed in t ha^{-1}. The weighed representative sample of green fodder collected from each net plot were sun dried and then oven dried @ 65 ± 5° C to obtain a constant weight. Dry matter content was calculated and dry matter yield (DMY) was worked out by multiplying the fresh fodder yield with dry matter content and expressed in t ha^{-1}.

Physiological and quality characters: The fully opened second leaf from top of the sample plant was used for the estimation of total chlorophyll content following the DMSO (dimethyl sulphoxide) method suggested by Yoshida *et al.* (1976). The absorbance was measured at 663 and 645 nm using spectrophotometer and total chlorophyll content was estimated and expressed in mg g^{-1} of fresh weight following Arnon (1949). The crude protein content at harvest was calculated by multiplying nitrogen content of the plant samples in per cent (on dry weight basis) with factor 6.25 (Simpson *et al*., 1965). Crude fibre content in the plant sample at harvest was determined following AOAC method (AOAC, 1975) and was expressed in percentage. Leaf area index (LAI) is the ratio of leaf area to ground area, which is a measure of photosynthetic area occupied by plant. Leaf area occupied by the sampling units was worked out using graph paper. For calculation of LAI, average of the leaf area to ground area ratios of each sampling unit from three replications was worked out. Leaf area duration (LAD) was calculated by the formula: LAD (days) = $(LAI_1 + LAI_2)/2 \times (t_2 - t_1)$; Specific leaf area (SLA) was calculated by selecting a fully expanded leaf. The area of leaf was recorded through graphical method. Leaf sample was oven dried at 70° C for about 24 hours till constant weight was obtained. SLA was calculated from the equation: SLA ($cm^2\ g^{-1}$) = LA/DW; where, LA is leaf area and DW is the dry weight.

Statistical analysis: The data generated from the experiment were statistically analyzed using analysis of variance technique (ANOVA) for 3 x 3 factorial RBD and significance was tested by applying 'F' test (Snedecor and Cochran, 1967). Wherever the F test values were found significant, the critical difference was computed at five percent probability level.

Results and Discussion

Growth parameters: The results revealed that growth characters like number of tillers $hill^{-1}$, GFY and DMY were significantly influenced by spacing but it failed to elicit any significant effect on height of plants. However, nitrogen levels and S x N interaction significantly affected all the growth as well as yield parameters (Table 1). The data on plant height clearly revealed that height of plants increased with increase in levels of nitrogen application and highest dose (N_3) recorded the maximum plant height (102.53 cm). It is well established that nitrogen has pivotal role in increasing chlorophyll content in plant, which fuels the plant growth converting the sunlight into chemical energy. The higher doses of nitrogen might also have enhanced the carbohydrate synthesis which in turn resulted in production of taller plants. Kadam *et al*. (2020) also observed a significant increase in plant height, number of tillers, GFY and DMY due to application of 120 kg ha^{-1} nitrogen over lower nitrogen levels. This increase in height of plants with different levels of nitrogen could also be attributed to the fact that it enhances number and length of internodes which in turn results in progressive rise in height of fodder oat (Gasim, 2001). Among different treatment combinations, fodder oat planted at 35 cm spacing with nitrogen application of 120 kg ha^{-1} (S_3N_3) recorded the maximum plant height (111.92 cm) and was at par with S_1N_3. Wider spacing together with higher nitrogen availability resulted in higher plant height due to reduced competition and greater availability of nutrients and other growth affecting factors. This result was in agreement with the finding of Manjunath *et al.* (2013) who reported higher plant height in fodder sorghum with increase in nitrogen levels at wider spacing.

Spacing, nitrogen levels and their interaction had significant effect on number of tillers $hill^{-1}$. Wider row spacing (35 cm) recorded the maximum number of

Table 1. Effect of row spacing, nitrogen levels and their interaction on growth, yield and quality attributes

Treatments	Plant height (cm)	Number of tillers per hill	GFY (t ha^{-1})	Dry fodder yield (t ha^{-1})	Crude fiber (%)	Crude protein (%)
Row spacing (S)						
S_1 (15 cm)	86.61	8.28	26.58	5.32	29.31	12.31
S_2 (25 cm)	90.11	8.98	22.18	4.44	29.59	12.29
S_3 (35 cm)	88.31	9.22	22.12	4.42	29.07	12.00
SEM	2.43	0.01	0.79	0.16	0.222	0.17
LSD (P<0.05)	NS	0.007	2.363	0.473	NS	NS
Nitrogen levels (N)						
N_1 (60 kg ha^{-1})	77.41	8.68	18.61	3.72	29.26	11.79
N_2 (90 kg ha^{-1})	85.09	8.82	24.57	4.92	29.37	12.27
N_3 (120 kg ha^{-1})	102.53	8.99	27.69	5.54	29.34	12.54
SEM	2.43	0.01	0.79	0.16	0.222	0.17
LSD (P<0.05)	7.292	0.007	2.363	0.473	NS	0.521
S x N interaction						
S_1N_1	72.33	8.08	23.49	4.69	29.23	12.13
S_1N_2	80.83	8.28	26.09	5.22	29.37	12.25
S_1N_3	106.67	8.48	30.14	6.03	29.33	12.54
S_2N_1	88.60	8.78	13.79	2.76	29.50	12.10
S_2N_2	92.00	8.98	25.66	5.13	29.57	12.27
S_2N_3	89.73	9.18	27.09	5.42	29.70	12.52
S_3N_1	71.28	9.18	18.55	3.71	29.03	11.15
S_3N_2	82.46	9.19	21.96	4.39	29.17	12.29
S_3N_3	111.19	9.29	25.85	5.17	29.00	12.56
SEM	4.21	0.01	1.37	0.27	0.385	0.30
LSD (P<0.05)	12.63	0.011	4.093	0.819	NS	NS

tillers $hill^{-1}$ (9.22) and narrow spacing (15 cm) recorded the minimum number of tillers $hill^{-1}$ (8.28). This might be because of the lesser plant population, provided more space, solar radiation, nutrients and soil moisture, which favoured the profuse tillering (Ayub *et al.,* 2013). Rasul *et al.* (2012) indicated that more tiller count under wider row spacing was due to the increased availability of sunlight and other resources in comparison to dense population due to narrow spacing. Among nitrogen levels, maximum tiller production was recorded with nitrogen application of 120 kg ha^{-1} (N_3) and the minimum tiller production was recorded with the application of 60 kg ha^{-1} nitrogen (N_1). Since nitrogen is the most crucial element for growth of plants, increased availability of nutrients contributed to higher tiller production in fodder oat. Sharma and Verma (2004) also recorded similar trend in oats regardless of the varieties. Among treatment combinations, fodder oat planted at 35 cm spacing with 120 kg ha^{-1} nitrogen application (S_3N_3) produced the maximum number of tillers per hill. Wider spacing together with higher nitrogen dose facilitated increased availability of sunlight, moisture as well as reduced competition for other growing factors leading to enhanced tiller production.

Biomass yield: As seen from the result that spacing, nitrogen levels and their interaction had significant effect on the GFY of fodder oat. Narrow row spacing (S_1- 15 cm) produced the highest GFY (26.58 t ha^{-1}). The higher GFY in closer spacing might be due to increased plant population than in 25 cm and 35 cm row spacing. Within nitrogen levels, maximum GFY was recorded at highest nitrogen dose (120 kg ha^{-1}). Mahale *et al.* (2003) reported a rise in green and dry forage yields with rise in nitrogen doses. According to Devi *et al.* (2009) application of nitrogen resulted in an increase in protoplasm of cell which in turn caused an increase in size of cell which altogether increased the growth and yield attributes. Within treatment combinations, fodder oat planted at 15 cm row spacing under 120 kg ha^{-1} nitrogen fertilization (S_1N_3) recorded the maximum green fodder yield.

As evident from the results that spacing, nitrogen levels and their interaction had significant effect on DMY of fodder oat. Similar to trend in GFY, narrow row spacing (S_1- 15 cm) recorded the maximum DFY (5.32 t ha^{-1}), since the DMY is product of GFY multiplied with dry matter content. The higher DMY in narrow spacing might be due to more plant population in 15 cm row spacing compared to the plant population at wider row spacing. Maximum DMY (5.54 t ha^{-1}) was recorded at higher nitrogen dose (120 kg ha^{-1}). The present finding indicated that the effect of nitrogen levels was in accordance with the findings of Bassegio *et al.* (2013), who reported that nitrogen had direct effect on dry fodder yield. According to Mahale *et al.* (2004) the increase in production of dry matter with increasing nitrogen levels up to 120 kg ha^{-1} was due to the parallel increase in height of plant, leaf area and number of tillers m^{-2} thereby high photosynthetic area which eventually increased the sink size and yielded more dry matter. Among treatment combinations, fodder oat planted at 15 cm row spacing under 120 kg ha^{-1} nitrogen fertilization (S_1N_3) recorded the maximum dry fodder yield.

Physiological parameters: The results revealed that spacing and S x N interaction had no significant effect on chlorophyll content while nitrogen levels had significant influence on chlorophyll content. Kathirvelan and Kalaiselvan (2006) opined that the content of chlorophyll is a varietal character and not much influenced by the spacing. Chlorophyll content was recorded to be highest under nitrogen fertilization of 120 kg ha^{-1} than at lower nitrogen doses (Table 2). Nitrogen is an indispensable part of leaf chlorophyll thus its application contributed to the increase in chlorophyll content at higher levels of nitrogen (Joshi *et al.,* 2015). Wang *et al.* (2022) narrated photosynthesis is vital for vegetative growth and fodder yield. In this process the physical energy of photons is transferred into the chemical energy of ATP and other reduced intermediate metabolites which are utilized in synthesis of carbon and nitrogen assimilates, carbohydrates and amino acids and other biochemical components, which led to increased chlorophyll synthesis. This result also confirmed the findings of Skudra and Ruza (2017), who recorded increase in chlorophyll content at higher levels of nitrogen fertilization.

As regards to leaf area index, spacing had no significant influence, whereas nitrogen levels significantly influenced the leaf area index. This could be attributed to the production of more and broad leaves at higher nitrogen levels. Bhavya *et al.* (2014) observed an increase in leaf production and leaf area which in turn resulted in higher leaf area index in fodder cowpea with increased levels of nitrogen. Effect of S x N interaction was not significant on leaf area index. Similarly, spacing did not exhibit any significant effect on leaf area duration, whereas nitrogen levels had significant influence on leaf area duration. Increase in leaf area with increase in nitrogen levels might have contributed to the increase in leaf area duration at higher levels of nitrogen. S x N interaction was found to be not significant on leaf area duration.

Results revealed that spacing, nitrogen levels and their interaction had significant effect on specific leaf area. Within spacing, S_2 followed by S_3 recorded the highest specific leaf area. This might be because of greater space available to the plant to grow, reduction in competition for nutrients resulting in higher leaf area in turn contributing to higher specific leaf area. Within nitrogen levels, N_3 recorded the highest specific leaf area. Rise in leaf area with rise in nitrogen levels might have enhanced specific leaf area at higher levels of nitrogen. Among treatments, S_2N_3 followed by S_3N_3 recorded the maximum specific

Table 2. Effect of row spacing, nitrogen levels and their interaction on Leaf area index (LAI), Leaf area duration (LAD), specific leaf area (SLA) and chlorophyll content

Treatments	LAI		LAD (days)	SLA (cm^2g^{-1})	Chlorophyll ($mg\ g^{-1}$)
	30 DAS	Harvest			
Row spacing (S)					
S_1 (15 cm)	2.89	3.24	134.89	351.03	3.02
S_2 (25 cm)	3.02	3.36	140.56	357.31	2.92
S_3 (35 cm)	2.83	3.17	131.97	353.73	3.09
SEM	0.10	0.10	4.22	0.71	0.15
LSD (P<0.05)	NS	NS	NS	2.121	NS
Nitrogen levels (N)					
N_1 (60 kg ha^{-1})	2.38	2.72	112.02	347.56	2.56
N_2 (90 kg ha^{-1})	2.94	3.28	136.89	351.29	2.92
N_3 (120 kg ha^{-1})	3.43	3.77	158.50	363.23	3.54
SEM	0.10	0.10	4.22	0.71	0.15
LSD (P<0.05)	0.287	0.287	12.636	2.121	0.436
S x N interaction					
S_1N_1	2.3	2.73	112.57	347.33	2.29
S_1N_2	3.052	3.39	141.76	350.47	3.15
S_1N_3	3.25	3.59	150.34	355.30	3.61
S_2N_1	2.35	2.69	110.93	349.00	3.03
S_2N_2	3.07	3.41	142.65	352.53	2.54
S_2N_3	3.65	3.99	168.09	370.40	3.16
S_3N_1	2.39	2.73	112.55	346.33	2.35
S_3N_2	2.70	3.04	126.28	350.87	3.07
S_3N_3	3.40	3.74	157.08	364.00	3.84
SEM	0.17	0.17	7.30	1.23	0.25
LSD (P<0.05)	NS	NS	NS	3.67	NS

leaf area; this might be because of the increase in leaf area at reduced competition for nutrients at wider spacing and availability of optimum nutrients for plant growth at higher nitrogen levels.

Quality characters: The result revealed that spacing, nitrogen levels and S x N interaction had no significant effect on crude fibre content of fodder oat. Coblentz *et al*. (2017) opined that nitrogen application increased the succulence but it negatively affected the cell wall content. However, in different studies the effect of nitrogen fertilization was inconsistent because it was confounded by many other factors *viz*., climate, moisture regimes, soil characteristics etc. Hence in present study, spacing and nitrogen application might have failed to significantly enhance fibre components in plants *i.e*., cellulose and lignin. This was in accordance with the recordings of Singh *et al*. (2020) that crude fibre content was not significantly influenced by different levels of application of nitrogen.

The tabulated data revealed that spacing and S x N interaction effect had no significant effect on crude protein content of fodder oat, while nitrogen levels had significant influence on crude protein. Significantly higher crude protein content (12.54%) was observed at N_3 and that was at par with N_2. Nitrogen is an integral part of various metabolites like amino acids and protein, so altogether increased nitrogen in plants could have resulted in increased protein synthesis. The increase in crude protein content was caused by improvement in amino acid and protein synthesis due to increased nitrogen application (Dupas *et al*., 2016). Beneficial effect of nitrogen fertilization on crude protein content and yield was also recorded by Choudhary *et al*. (2016). Swathy and Thomas (2021) also recorded that nitrogen was directly involved in increasing amino acid formation. The above result agreed with the findings of Pradhan and Mishra (1994) that crude protein content increased significantly with each successive rise in nitrogen doses up to 120 kg ha^{-1}. This might be due to the certainty that higher nitrogen level leads to adequate nutrient availability which cause more nutrients uptake and corresponding increment in crude protein content of fodder.

Nitrogen-phosphorus-potassium uptake: Data revealed that row spacing, nitrogen levels and their interaction had significant effect on uptake of nitrogen, phosphorus and potassium (Table 3). The nitrogen, phosphorus and potassium uptakes were maximum under spacing, S_1 (15 cm) as the uptake was directly in proportion of biomass yields. Hence, due to higher biomass yield under narrow spacing S_1 (15 cm) manifested increased uptake. Among nitrogen levels, N_3 (120 kg ha^{-1}) recorded the highest nitrogen, phosphorus and potassium. Higher nitrogen, phosphorus and potassium uptake at higher nitrogen level might be because of beneficial influence of nitrogen sufficiency in soil solution, its positive effect on all physiological and photosynthetic processes leading to higher dry matter yields resulting to an enhanced uptake. Sarkar and Mallick (2010) recorded that increased uptake of nutrients with nitrogen application might be because of enhanced uptake of nitrogen by greater root proliferation and anchorage to deep penetration which in turn increased uptake from rhizosphere. Within treatment combinations, S_1N_3 recorded the highest nitrogen uptake and was found at par with S_2N_3. Higher plant population together with high nitrogen doses might have contributed to high nitrogen uptake. Phosphorus uptake was recorded maximum at S_1N_3 (27.91 kg ha^{-1}) and was found at par with S_2N_3 having phosphorus uptake (25.29 kg ha^{-1}). In case of K uptake, treatment combination S_1N_3 recorded higher potassium uptake (100.46 kg ha^{-1}) and was found at par with S_2N_3 having potassium uptake (89.96 kg ha^{-1}). The lowest spacing adopted coupled with the application of high doses of nitrogen might have stimulated phosphorus and potassium uptake. These findings were in confirmation with the findings of Kadam *et al.* (2020) that nitrogen, phosphorus and potassium uptake was increased with increasing nitrogen levels.

Table 3. Effect of row spacing, nitrogen levels and their interaction on uptake N, P and K by fodder oat

Treatments	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
Row spacing (S)			
S_1 (15 cm)	104.81	24.47	88.32
S_2 (25 cm)	87.55	20.51	73.50
S_3 (35 cm)	85.33	20.46	73.57
SEM	3.182	0.741	2.682
LSD (P<0.05)	9.519	2.215	8.022
Nitrogen levels (N)			
N_1 (60 kg ha^{-1})	70.07	17.01	61.59
N_2 (90 kg ha^{-1})	96.47	22.72	81.41
N_3 (120 kg ha^{-1})	111.15	25.72	92.38
SEM	3.172	0.738	2.673
LSD (P<0.05)	9.519	2.215	8.022
S x N interaction			
S_1N_1	91.18	21.32	77.85
S_1N_2	102.28	24.18	86.65
S_1N_3	120.97	27.91	100.46
S_2N_1	53.34	12.62	45.72
S_2N_2	100.75	23.61	84.84
S_2N_3	108.56	25.29	89.96
S_3N_1	65.69	17.07	61.22
S_3N_2	86.37	20.37	72.76
S_3N_3	103.92	23.94	86.72
SEM	5.49	1.28	4.63
LSD (P<0.05)	16.487	3.836	13.894

Conclusion

It was concluded that fodder oat could be profitably cultivated in high range tract of Kerala, (AEU 20-Wayanad Eastern Plateau) at a row spacing of 15 cm with application of 120 kg ha^{-1} nitrogen in two splits at basal (60%) and 40 DAS (40%), and basal application of 40 kg ha^{-1} P_2O_5, 40 kg ha^{-1} K_2O and 15 t ha^{-1} of FYM.

Acknowledgment

Authors are grateful to authorities of Kerala Agricultural University, Kerala and AICRP FCU, Jhansi for their supports.

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