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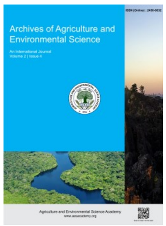

ORIGINAL RESEARCH ARTICLE

CrossMark

Effects of plant spacing and nitrogen level on the green fodder yield of maize (*Zea mays* L.)

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ABSTRACT

An experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during December 2016 to February 2017 to investigate the effect of plant spacing and nitrogen level on growth parameters and green fodder yield of maize (*Zea mays* L.). The experiment comprised three plant spacings *viz.*, 35 cm × 10 cm, 35 cm × 20 cm, 35 cm × 30 cm and three nitrogen levels *viz.*, 100, 150 and 200 kg N ha^{-1}. The experiment was laid out in a randomized complete block design with three replications. Results revealed that plant spacing, nitrogen levels and their interaction had significant effect on growth parameters and green fodder yield. The tallest plant (192.5 cm) was obtained at plant spacing 35 cm × 30 cm, while the highest fodder yield (61.13 t ha^{-1}) of *Z. mays* was recorded at 35 cm × 10 cm spacing. In case of nitrogen level, the tallest plant (204.9 cm), the highest number of leaves plant^{-1} (12.22), the highest chlorophyll content in leaves (41.50) and the highest fodder yield (70.38 t ha^{-1}) of *Z. mays* were recorded in 200 kg N ha^{-1}. In case of interaction, the tallest plant (218.4 cm) of *Z. mays* was produced at spacing 35 cm × 30 cm along with 200 kg N ha^{-1}. The highest fodder yield (78.01 t ha^{-1}) of *Z. mays* was obtained at spacing 35 cm × 10 cm fertilized with 200 kg N ha^{-1} which was at par with spacing 35 cm × 20 cm fertilized with 200 kg N ha^{-1} and the lowest fodder yield (31.91 t ha^{-1}) was obtained at spacing 35 cm × 30 cm along with 100 kg N ha^{-1}. Therefore, spacing 35 cm × 10 cm fertilized with 200 kg N ha^{-1} appears as the promising practice for maize cultivation as fodder crop.

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INTRODUCTION

Maize (*Zea mays* L.) is used as multipurpose crop such as food, feed, and fodder crop in Bangladesh. Maize is a very convenient crop for fodder production due to the high production of green mass per unit area, high energy content of dry matter and quality of biomass for silage (Mandić *et al.*, 2013). It is extensively grown in temperate, subtropical and tropical regions of the world throughout the year mainly due to its photo-thermo-insensitive character (Verma, 2011). In Bangladesh, it can be grown in both *Rabi* and *Kharif* season. The cultivation of maize has been gaining popularity in the recent years for its high productivity and diversified use in Bangladesh (Tajul *et al.*, 2013). Maize crop has been included as a major enterprise in the crop diversification and intensive cropping programmes (Zamir *et al.*, 2011). Although the soil and climatic conditions of Bangladesh are favorable for the maize production, but it's per ha^{-1} fodder yield is very low as compared to other country of the world. Low yield of maize was due to many agronomic factors, but plant spacing and nitrogenous fertilizer application is considered most important factors which can increase fodder production significantly. Among the agronomic practices that influence crop growth and seed yield, plant spacing and fertilizer management are the prominent ones. Competition associated with different spacing alters plant morphology in various ways. As such there is a considerable scope for increasing yield by adjusting optimum plant spacing. High density is undesirable because it encourages inter-plant competition for resources while resource will simply be misuse under sparse plant spacing (Salam *et al*., 2010).

Nitrogen is a primary nutrient required by crop plants for their growth and development. Nitrogen plays an important role in building up of protoplast and protein, which induce cell division and initiate epistemic activities when applied in optimum quantity. The application of nitrogen not only affects the forage yield of maize, but also improves its quality especially its protein contents (Haque *et al*., 2001). It is reported that application of nitrogen to maize increase fodder nutritive value by increasing crude protein and by reducing ash and fiber contents. Study on nitrogen management and spacing would enrich the knowledge on development of management tools for higher fodder yield per unit area of this crop. This study was therefore, undertaken to determine the optimum spacing and nitrogen fertilizer on growth and fodder yield of maize (*Zea mays* L.).

MATERIALS AND METHODS

Experimental sites and experimentation

The experiment was carried out at the Agronomy Field Laboratory, Department of Agronomy, Bangladesh Agricultural University, Mymensingh during December 2016 to February 2017. The experiment site located at 24°75' N latitude and 90° 50' E longitude having an altitude of 18 m above the mean sea level. The experimental site belongs to the Sonatala series of Old Brahmaputra Floodplain Agro ecological Zone (AEZ-9) having non-calcareous dark grey floodplain soils (UNDP and FAO, 1998). The experiment was done in a randomized complete block design with three replications having three plant spacings *viz*., 35 cm × 10 cm, 35 cm × 20 cm, 35 cm × 30 cm and three nitrogen levels *viz*., 100, 150 and 200 kg N ha^{-1}. The size of each unit plot was 2.5 m × 2.0 m. The land was fertilized with triple super phosphate (TSP), muriate of potash (MoP), gypsum and zinc sulphate @ 270 kg, 220 kg, 220 kg and 15 kg ha^{-1}, respectively. Nitrogen was applied in the form of prilled urea as per treatment of the experiment in three equal splits. One-third of the urea and entire amount of triple super phosphate, muriate of potash, gypsum and zinc sulphate were applied at final land preparation and the remaining urea was applied in two equal splits at 20 and 50 days after sowing (DAS). Rows were oriented length wise in north-south direction. Seeds of *Z. mays* were sown on 5 December 2016 as per experimental spacing apart by opening 3-4 cm deep furrows with tine. BARI developed maize cultivar BARI hybrid maize 9 was used as test crop. Two seeds were sown in each hill^{-1}. Weeding was done at 15 and 30 DAS. Only one healthy seedling hill^{-1} was kept and the rest were thinned out at 15 DAS (at the time of first weeding). The crop of *Z. mays* was irrigated two times at 20 and 50 DAS after topdressing of urea.

Data collection

Five plants were randomly with bamboo sticks in each plot excluding border rows to record the data on vegetative characters. Chlorophyll meter values (SPAD) were recorded using a portable SPAD meter (Model SPAD-502, Minolta crop, Ramsey, NJ). The instrument measures transmission of red light at 650 nm, at which chlorophyll absorbs light and transmission of infrared light at 940 nm, at which no absorption occurs. The chlorophyll meter readings have been positively correlated with destructive chlorophyll measurements in many crop species (Zhu *et al*., 2012) and considered as a useful indicator of the need of N top dressing during the crop growth on the basis of these two transmission values, the instrument calculates a SPAD value that is well correlated with chlorophyll content (Paul *et al*., 2018). At silking and milk stage (of the grain), the crop was harvested plot-wise and converted into t ha^{-1}.

Statistical analysis

The collected data were statistically analyzed using "Analysis of Variance" technique with the help of computer program, MSTAT. Mean differences among the treatments were adjudged by using the Duncun's Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Plant height of *Z. mays*

Plant height of *Z. mays* was significantly influenced by plant spacing at 30 DAT and at harvest. At 30 DAT, the tallest plant (68.06 cm) was obtained in 35 cm × 30 cm plant spacing, which was statistically identical to spacing 35 cm × 10 cm and the shortest plant (62.64 cm) was obtained in 35 cm × 20 cm plant spacing (Table 1). At 45 DAT, numerically the tallest plant (91.89 cm) of *Z. mays* was obtained in 35 cm × 30 cm spacing and the shortest plant (87.03 cm) of *Z. mays* was obtained at spacing 35 cm × 10 cm (Table 1). At harvest, the tallest plant (192.5 cm) of *Z. mays* was obtained in spacing 35 cm × 30 cm followed by 35 cm × 20 cm spacing and the shortest one (158.3 cm) of *Z. mays* was obtained at 35 cm × 10 cm plant spacing (Table 1). Nitrogen fertilization has significant influence on plant height at 30, 45 DAT and at harvest. At 30 DAT, the tallest plant (70.89 cm) was obtained in 200 kg N ha^{-1}, which was statistically identical to 150 kg N ha^{-1} and the shortest on (58.75 cm) was obtained when fertilized with 100 kg N ha^{-1} (Table 2). At 45 DAT, the tallest plant (100.6 cm) of *Z. mays* was obtained in 200 kg N ha^{-1} followed by 150 kg N ha^{-1} and the shortest plant (81.44 cm) of *Z. mays* was obtained in 100 kg N ha^{-1} (Table 2). At harvest, the tallest plant (204.9 cm) of *Z. mays* was obtained from 200 kg N ha^{-1} followed by 150 kg N ha^{-1} and the shortest plant (155.4 cm) of *Z. mays* was obtained from 100 kg N ha^{-1} (Table 2). Plant height was increased significantly with increase nitrogen levels were reported by Ullah *et al*. (2015) and Khan *et al*. (2014). The interaction between plant spacing and nitrogen fertilization has significant influence on plant height at 30, 45 DAT and at harvest. At 30 DAT, the tallest plant (72.08 cm) of *Z. mays* was obtained at spacing 35 cm × 20 cm fertilized with 200 kg N ha^{-1}, which was statistically identical to the plant spacing 35 cm × 10 cm fertilized with 200 kg N ha^{-1}, spacing 35 cm × 30 cm fertilized with 100 kg N ha^{-1}, spacing 35 cm × 30 cm along with 150 kg N ha^{-1} and plant spacing 35 cm × 30 cm fertilized with 200 kg N ha^{-1} and the shortest plant (52.17 cm) of *Z. mays* was obtained at the spacing 35 cm × 20 cm along with 100 kg N ha^{-1}, which was statistically identical to spacing 35 cm × 10 cm fertilized with 100 kg N ha^{-1} (Table 3). At 45 DAT, the tallest plant (103.3 cm) was obtained from the spacing 35 cm × 10 cm along with 200 kg N ha^{-1}, which was statistically identical to spacing 35 cm × 20 cm fertilized with 200 kg N ha^{-1}, spacing 35 cm × 30 cm along with 150 kg N ha^{-1} and 35 cm × 30 cm spacing along with 200 kg N ha^{-1} and the shortest plant (74.83 cm) of *Z. mays* was obtained from spacing 35 cm × 10 cm combined with 100 kg N ha^{-1}, which was statistically identical to plant spacing 35 cm × 10 cm fertilized with 150 kg N ha^{-1}, 35 cm × 20 cm along with 100 kg N ha^{-1}, 35 cm × 20 cm fertilized with 150 kg N ha^{-1} and 35 cm × 30 cm fertilized with 100 kg N ha^{-1} (Table 3). At harvest, the tallest plant (218.4 cm) of *Z. mays* was obtained from the plant spacing 35 cm × 30 cm fertilized with 200 kg N ha^{-1}, which was statistically identical to spacing 35 cm × 20 cm along with 200 kg N ha^{-1} and 35 cm × 30 cm along with 150 kg N ha^{-1} and the shortest plant (128.8 cm) of *Z. mays* was obtained at 35 cm × 10 cm spacing along with 100 kg N ha^{-1}, which was statistically identical to spacing 35 cm × 30 cm fertilized with 100 kg N ha^{-1} (Table 3).

Table 1. Effect of plant spacing on vegetative characters of *Z. mays* as fodder crop.

Planting Spacing	Crop characters at different days after sowing					
	30 DAS		45 DAS		At harvest	
	Plant height (cm)	Number of leaves plant^{-1}	Plant height (cm)	Number of leaves plant^{-1}	Plant height (cm)	Number of leaves plant^{-1}
35 cm × 10 cm	63.06ab	8.33b	87.03	9.67	158.3c	10.89
35 cm × 20 cm	62.64b	8.44ab	90.08	9.89	187.3b	11.44
35 cm × 30 cm	68.06a	9.11a	91.89	10.11	192.5a	11.11
$S_{\bar{x}}$	2.91	0.41	5.28	0.44	9.70	0.47
Level of significance	*	*	NS	NS	**	NS
CV (%)	7.80	8.38	10.21	7.72	9.37	7.37

In a column, figures with same letter(s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT), ** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Not significant.

Table 2. Effect of nitrogen level on vegetative characters of *Z. mays* as fodder crop.

Level of nitrogen (kg ha^{-1})	Crop characters at different days after sowing					
	30 DAS		45 DAS		At harvest	
	Plant height (cm)	Number of leaves plant^{-1}	Plant height (cm)	Number of leaves plant^{-1}	Plant height (cm)	Number of leaves plant^{-1}
100	58.75c	8.44	81.44c	9.53	155.4c	10.56b
150	64.11ab	8.44	86.9 b	9.56	177.8b	10.67b
200	70.89a	9.00	100.6a	10.60	204.9a	12.22a
$S_{\bar{x}}$	2.90	0.42	5.23	0.93	9.70	0.47
Level of significance	**	NS	**	NS	**	*
CV (%)	7.80	8.38	10.21	7.72	9.37	7.37

In a column, figures with same letter(s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT), ** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Not significant. N_1 =100 kg/ha, N_2 =150 kg/ha, N_3=200 kg/ha.

Table 3. Effect of interaction between spacing and nitrogen level on vegetative characters of *Z. mays* as fodder crop.

Planting Spacing	Level of nitrogen (kg ha^{-1})	Crop characters at different days after sowing					
		30 DAS		45 DAS		At harvest	
		Plant height (cm)	Number of leaves plant^{-1}	Plant height (cm)	Number of leaves plant^{-1}	Plant height (cm)	Number of leaves plant^{-1}
35 cm × 10 cm	100	58.58cd	8.33	74.83c	9.33	128.8e	10.00
	150	59.67c	7.66	83.00bc	9.00	162.3cd	10.33
	200	70.92ab	9.00	103.3a	10.67	183.8bc	12.33
35 cm × 20 cm	100	52.17d	8.33	81.83bc	9.33	185.3bc	10.67
	150	63.67bc	8.33	85.50bc	10.00	164.2cd	11.33
	200	72.08a	8.66	102.9a	10.33	212.3ab	12.33
35 cm × 30 cm	100	65.50abc	8.66	87.67bc	10.00	152.3de	11.00
	150	69.00ab	9.33	92.33ab	9.66	206.8ab	10.33
	200	69.67ab	9.33	95.67ab	10.67	218.4a	12.00
$S_{\bar{x}}$		2.90	0.41	5.28	0.44	9.70	0.47
Level of significance		*	NS	*	NS	**	NS
CV (%)		7.80	8.38	10.21	7.72	9.37	7.37

In a column, figures with same letter(s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT), ** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Not significant.

Number of leaves plant^{-1} of *Z. mays*

Number of leaves plant^{-1} was significantly influenced by plant spacing at 30 DAT. At 30 DAT, the highest number of leaves plant^{-1} (9.11) of *Z. mays* was obtained at spacing 35 cm × 30 cm, which was statistically identical to 35 cm × 20 cm spacing and the lowest number of leaves plant^{-1} (8.33) of *Z. mays* was obtained at 35 cm × 10 cm spacing (Table 1). At 45 DAT, numerically the highest number of leaves plant^{-1} (10.11) of *Z. mays* was obtained at spacing 35 cm × 30 cm followed by 35 cm × 20 cm spacing and the lowest number of leaves plant^{-1} (9.67) of *Z. mays* was obtained in 35 cm × 10 cm spacing (Table 1). At final harvest, numerically the highest number of leaves plant^{-1} (11.44) of *Z. mays* was obtained at the spacing 35 cm × 20 cm followed by 35 cm × 30 cm spacing and the lowest number of leaves plant^{-1} (10.89) of *Z. mays* was obtained at 35 cm × 10 cm spacing (Table 1). Lamana (2007) reported that the wider plant spacing had a positive effect on number of leaves plant^{-1}. Nitrogen fertilization has significant influence on number of leaves plant^{-1} at harvest. At 30 DAT, numerically the highest number of leaves plant^{-1} (9.00) of *Z. mays* was obtained in 200 kg N ha^{-1} and the lowest number of leaves plant^{-1} (8.44) of *Z. mays* was obtained from 150 kg N ha^{-1} and 100 kg N ha^{-1} (Table 2). At 45 DAT, numerically the highest number of leaves plant^{-1} (10.60) of *Z. mays* was obtained in 200 kg N ha^{-1} followed by 150 kg N ha^{-1} and the lowest number of leaves plant^{-1} (9.53) of *Z. mays* was obtained in 100 kg N ha^{-1} (Table 2). At harvest, the highest number of leaves plant^{-1} (12.22) of *Z. mays* was obtained from 200 kg N ha^{-1} and the lowest number of leaves plant^{-1} (10.56) of *Z. mays* was obtained in 100 kg N ha^{-1}, which was statistically identical to 150 kg N ha^{-1} (Table 2). Number of leaves plant^{-1} was increased significantly with increase nitrogen levels was reported by Khan *et al.* (2014). The interaction between plant spacing and nitrogen fertilization has no significant influence on number of leaves plant^{-1} at 30 DAT, at 45 DAT and at final harvest. At 30 DAT, numerically the highest number of leaves plant^{-1} (9.33) was obtained at spacing 35 cm × 30 cm fertilized with 150 kg N ha^{-1} and spacing 35 cm × 30 cm along with 200 kg N ha^{-1} followed by spacing 35 cm × 10 cm along with 200 kg N ha^{-1} and the lowest number of leaves plant^{-1} (7.66) was obtained at spacing 35 cm × 10 cm along with 150 kg N ha^{-1} (Table 3). At 45 DAT, numerically the highest number of leaves plant^{-1} (10.67) of *Z. mays* was obtained at plant spacing 35 cm × 10 cm along with 200 kg N ha^{-1} and spacing 35 cm × 30 cm along with 200 kg N ha^{-1} followed by spacing 35 cm × 20 cm along with 200 kg N ha^{-1} and the lowest number of leaves plant^{-1} (9.00) of *Z. mays* was obtained at spacing 35 cm × 10 cm along with 150 kg N ha^{-1} (Table 3). At harvest, numerically the highest number of leaves plant^{-1} (12.33) of *Z. mays* was obtained at 35 cm × 10 cm spacing along with 200 kg N ha^{-1} and spacing 35 cm × 20 cm along with 200 kg N ha^{-1} followed by spacing 35 cm × 30 cm along with 200 kg N ha^{-1} and the lowest number of leaves plant^{-1} (10.00) of *Z. mays* was obtained at spacing 35 cm × 10 cm along with 100 kg N ha^{-1} (Table 3).

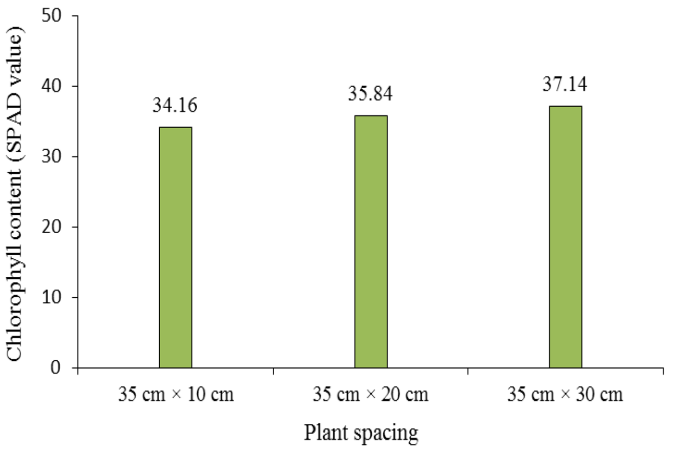

Figure 1. *Effect of plant spacing on chlorophyll content of Z. mays as fodder crop.*

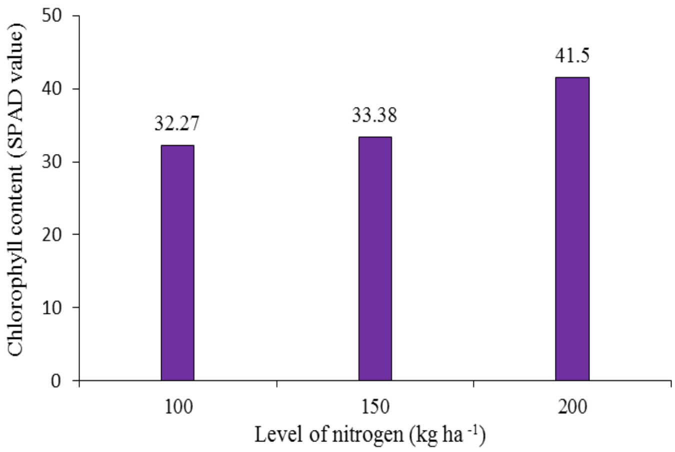

Figure 2. *Effect of level of nitrogen on chlorophyll content of Z. mays as fodder crop.*

Leaf chlorophyll content (SPAD value)

Chlorophyll content was significantly influenced by plant spacing. The highest chlorophyll content (37.14) of *Z. mays* was obtained at spacing 35 cm × 30 cm, which was statistically identical to 35 cm × 20 cm spacing and the lowest chlorophyll content (34.16) of *Z. mays* was obtained at the spacing 35 cm × 10 cm (Figure 1). Nitrogen fertilization has significant influence on chlorophyll content. The highest chlorophyll content (41.50) was obtained in 200 kg N ha^{-1} and the lowest chlorophyll content (32.27) of *Z. mays* was obtained from 100 kg N ha^{-1}, which was statistically identical to 150 kg N ha^{-1} (Figure 2). Leaf Chlorophyll Content was increased significantly with increase nitrogen levels was reported by Ullah *et al.* (2015). The interaction between plant spacing and nitrogen fertilization has significant influence on chlorophyll content. The highest chlorophyll content (45.30) of *Z. mays* was obtained at spacing 35 cm × 10 cm fertilized with 200 kg N ha^{-1}, which was statistically identical to spacing 35 cm × 20 cm along with 100 kg N ha^{-1}, 35 cm × 20 cm along with 200 kg N ha^{-1}, 35 cm × 30 cm along with 100 kg N ha^{-1}, 35 cm × 30 cm along with 150 kg N ha^{-1} and 35 cm × 30 cm along with 200 kg N ha^{-1} and the lowest chlorophyll content (25.73) of *Z. mays* was obtained at spacing 35 cm × 10 cm along with 100 kg N ha^{-1}, which was statistically identical to spacing 35 cm × 10 cm along with 150 kg N ha^{-1}, 35 cm × 20 cm along with 100 kg N ha^{-1}, 35 cm × 20 cm along with 150 kg N ha^{-1}, 35 cm × 30 cm along with 100 kg N ha^{-1} and 35 cm × 30 cm along with 150 kg N ha^{-1} (Figure 3).

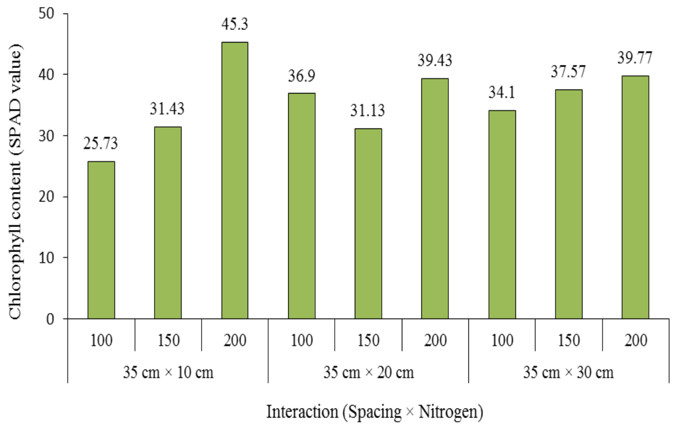

Figure 3. *Effect of interaction between plant spacing and level of nitrogen (kg ha^{-1}) on chlorophyll content of Z. mays as fodder crop.*

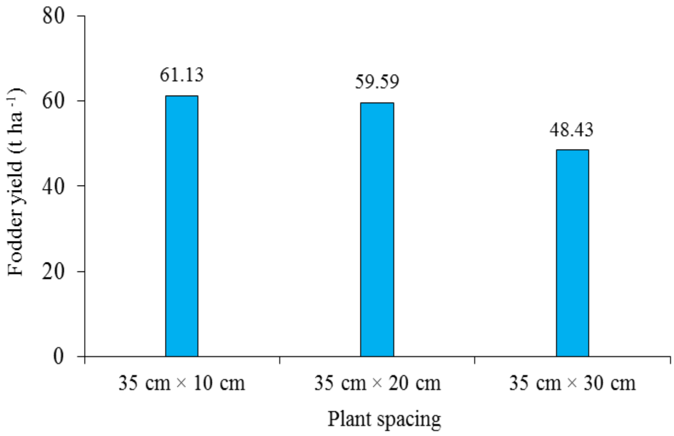

Figure 4. *Effect of plant spacing on fodder yield of Z. mays.*

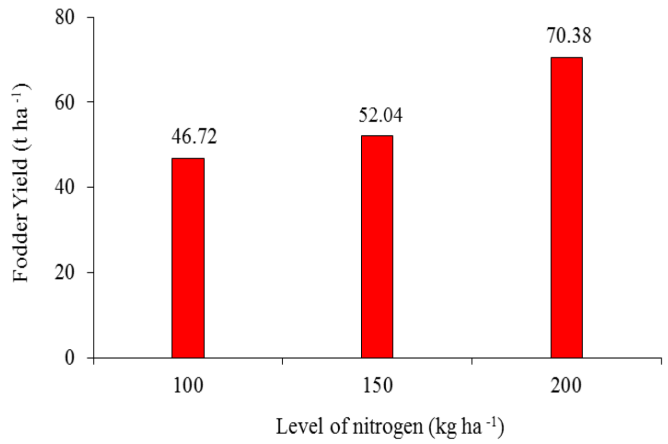

Figure 5. *Effect of level of nitrogen on fodder yield of Z. mays.*

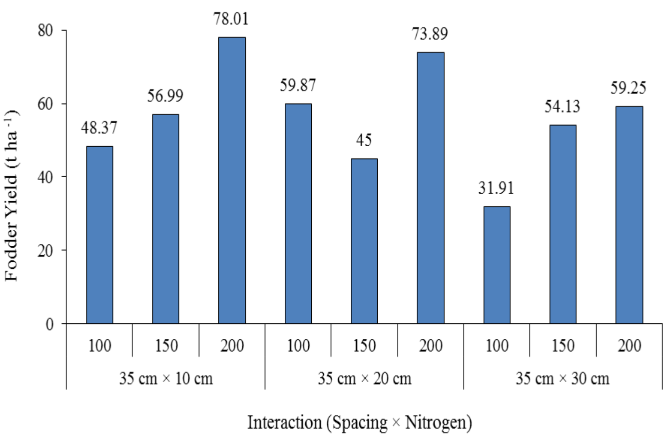

Figure 6. *Effect of interaction between plant spacing and level of nitrogen (kg ha^{-1}) on fodder yield of Z. mays.*

Fodder yield of *Z. mays*

Fodder yield was significantly influenced by plant spacing. The highest fodder yield (61.13 t ha $^{-1}$) of *Z. mays* was obtained at the plant spacing 35 cm × 10 cm followed by spacing 35 cm × 20 cm and the lowest fodder yield (48.43 t ha $^{-1}$) of *Z. mays* was obtained at spacing 35 cm × 30 cm (Figure 4). Nitrogen fertilization has significant influence on fodder yield. The highest fodder yield (70.38 t ha $^{-1}$) of *Z. mays* was obtained in 200 kg N ha^{-1} followed by 150 kg N ha^{-1} and the lowest fodder yield (46.72 t ha $^{-1}$) of *Z. mays* was obtained in 100 kg N ha^{-1} (Figure 5). Similar results were reported by Khan *et al.* (2014), who reported that application of nitrogen fertilization significantly increased fodder yield of maize. The interaction between plant spacing and nitrogen fertilization has significant influence on fodder yield of *Z. mays*. The highest fodder yield (78.01 t ha $^{-1}$) of *Z. mays* was obtained at plant spacing 35 cm × 10 cm fertilized with 200 kg N ha^{-1}, which was statistically identical to spacing 35 cm × 20 cm fertilized with 200 kg N ha^{-1} and the lowest fodder yield (31.91 t ha $^{-1}$) of *Z. mays* was obtained at spacing 35 cm × 30 cm fertilized with 100 kg N ha^{-1} (Figure 6).

Conclusion

Plant spacing and nitrogen fertilization has significant influence on vegetative growth and green fodder yield of maize. Results of the study revealed that the tallest plant, the highest number of leaves plant^{-1} at 45 DAT, the highest number of leaves plant^{-1} at harvest and the highest chlorophyll content of *Z. mays* were produced by 35 cm × 10 cm plant spacing fertilized with 200 kg N ha^{-1}. The highest fodder yield of *Z. mays* was obtained in spacing 35 cm × 10 cm fertilized with 200 kg N ha^{-1}, which was as good as 35 cm × 20 cm spacing fertilized with 200 kg N ha^{-1} while the lowest fodder yield of *Z. mays* was obtained at spacing 35 cm × 30 cm along with 100 kg N ha^{-1}. Therefore, spacing 35 cm × 10 cm along with 200 kg N ha^{-1} appears as the promising practice of *Z. mays* cultivation in terms green fodder yield.

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