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Influence of Date of Planting, Nitrogen Application and Planting Geometries on Growth, Biomass Yield and Essential Yield of Palmarosa (*Cymbopogon martinii* Roxb. Wats) under Sub-Mountainous Region of Punjab

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A field experiment was conducted at Punjab Agricultural University, Regional Research Station, Gurdaspur during two year crop cycles of 2013-14 and 2014-15 to find out the effect of date of planting, nitrogen application and planting geometries on the biomass yield and essential oil yield of palmarosa under sub-mountainous region of Punjab. The experiment was laid out in split-split plot design having three replications with three planting dates of palmarosa viz. April 25, May 10 &May 25, three nitrogen levels (50, 100 and 150 kg ha^{-1}) in sub-plots and three planting geometries (60cm×30 cm, 60cm×45cm and 60 cm×60 cm) in sub-sub plots during two year crop cycles. The highest biomass yield and essential oil yield were recorded in April 25 which obtained higher biomass yield and essential oil yield than May 10 and May 25 at each harvest during both the years of crop cycles. Also, higher biomass yield and essential oil yield were recorded in crop raised with 150 kg N ha^{-1} which was statistically at par with 100 kg N ha^{-1} during each harvest of palmarosa. Among planting geometries, the highest biomass yield and essential oil yield were observed in planting geometries 60cm×30cm, which were significantly superior to 60cm×60cm and 60cm×45cm. Further, date of planting, nitrogen application and planting geometries did not cause significant variation in the oil concentration.

Introduction

Palmarosa (*Cymbopogon martinii* Roxb. wats) is tall, multi-cut, perennial aromatic grass belonging to family Poaceae. It is having fibrous shallow roots, erect culms over 1.5 - 2.5 m tall with swollen nodes. The leaf sheath is glabrous, membranous ligule with flat and linear leaf blades. Inflorescence is large compound panicle. Mature seeds of palmarosa are brown, fine, hairy and easily disposed by air. The grass is also referred as “Rosha grass” which yields an essential oil on hydro-distillation of its biomass. This essential oil is present in all parts of palmarosa viz., inflorescence, leaves and stem of which the inflorescence contains the major portion. Palmarosa oil is the best natural source of perfumery chemicals like geraniol (75%), geraniol acetate (20%), concentrations of linalool (2%), α-terpineol, geranyl isobutyrate, etc. (Rao *et al.,* 2005). Palmarosa is considered to be a native of India and grows wild in Madhya Pradesh, Karnatka, Uttar Pradesh, Bihar and Odisha. India ranks first among the palmarosa oil producing countries and is the major supplier to the world market. In India about 15 metric tonnes of palmarosa oil is produced annually both from cultivated and natural resources (Gingade *et al.*, 2014). Essential oil of palmarosa is pale yellow in colour, possessing a pleasant odour and is valued highly in cosmetics, perfumery industry (Mallavarapu *et al.,* 1998) and pharmaceutical products (Akhila, 2009). This oil possesses some of the important properties such as insect repellent (Das and Ansari, 2002) and action against various bacteria (Lodhia *et al.,* 2009), fungi (Bard *et al.*, 1988) and micro-organism (Rao *et al.,* 2009). Traditionally, palmarosa oil was used in treatment of skin infection like acne and also to stimulate cell generation, prevents ugly scarring in healing wounds, as a remedy for lumbago, stiff joints and bilious complaints. It is also used in aromatherapy (Fatima *et al.*, 2002). There are many factors that affect agronomic characteristics, biomass and essential oil yield of aromatic plants (Khazaie *et al.,* 2007). Date of planting, nitrogen requirement and planting geometries are amongst the most limiting factors for crop yield of environmentally sound agriculture. Plant age and crop density are among the most important factors that influence the yield of aromatic plants (Marotti *et al.,* 1994). The influence of spacing on agronomic characteristics, biomass, essential oil content and essential oil yield were also reported by Zewdinesh and Beeemnet, 2012 in palmarosa. Being a member of poaceae family, palmarosa crop responded well to nitrogenous fertilizers, which affect the essential oils yield of palmarosa by the increase of the production of total biomass per unit of area (Sarma *et al.*, 1977). Plant spacings, both row to row and plant to plant, play a significant role in the production of aromatic grasses. It is governed by various edapho-climatic factors to a large extent leading to varying results at different locations (Singh *et al.*, 2000). In the paucity of information on its cultivation under Punjab conditions, the present investigation was undertaken to study the effect of date of planting, nitrogen and planting geometries on growth, biomass and essential oil yield of palmarosa (*Cymbopogon martini* Roxb. wats.) under sub-mountainous region of Punjab.

Materials and Methods

Two field experiments each for two years were conducted during 2013-15 and 2014-2016 at Punjab Agricultural University Regional Research Station, Gurdaspur in sub-mountainous region of Punjab which is situated between 32°3′ N latitude, 75°22′ E longitude and has an altitude of about 257 m from mean sea level. The soil of experimental field was clayey loam in texture, medium in organic carbon (0.49%), medium in available P_2O_5 (21.8 kg ha^{-1}) and low in K_2O (93.8 kg ha^{-1}) at 0-15 cm soil depth. The soil was neutral in reaction (pH-7.1) with normal electric conductivity (0.33 ds m^{-1}). The experiment was laid out in split-split plot design having three replications with date of planting of palmarosa in main plots, nitrogen levels in sub-plots and planting geometries in sub-sub plots. It consists of three planting dates of palmarosa plot viz. April 25, May 10 &May 25, three nitrogen levels (50, 100 & 150 kg ha^{-1}) in sub-plots and three planting geometries (60cm×30 cm, 60cm×45cm & 60 cm×60 cm) in sub-sub plots during during two year crop cycles.

The palmarosa cultivar 'Kelkar' was propagated through 2.5 kg seed by raising seedling in nursery to transplant one hectare of main field. Raised nursery beds of 5×1 m were prepared with 50 cm height. Farm yard manure was added in seed bed. As seeds were very small and light in weight, they were mixed with fine soil for even distribution. Lines of 3 cm deep and 10 cm apart were made and the seeds were uniformly sown in lines and covered with soil. The beds were irrigated with rose can on alternate days. The seeds got germinated within 3-4 days and 30 days old seedlings were ready for transplanting in the main field.

The field was thoroughly ploughed and levelled. Established seedlings were transplanted in the main field according to the date of planting, fertilized as per treatments of respective level of nitrogen with different planting geometry treatments. The palmarosa crop was fertilized with 50 kg P_2O_5 ha^{-1} and 40 kg K ha^{-1} (Gosh and Chatterjee, 1976) through single super phosphate and muriate of potash, respectively. Nitrogen was applied in the form of urea in four equal splits one as basal and the rest after three harvests during each year. The whole quantity of phosphorous and potassium were applied prior to transplanting. The crop was irrigated immediately after plantation for better establishment of the crop, subsequently once in a week and thereafter as and when required. Irrigation should be discontinued 7-10 days before harvesting. Hand weeding was done as weeds affect the yield and quality of the oil. The crop is kept weed free by periodical weeding for 1-2 months during early establishment period. After each harvest, a hoeing was done followed by irrigation. Three harvests were taken in each year after 120 days interval. The crop was manually harvested at full flowering stage with sickle leaving 15 cm stubble from ground level, which grew and yielded subsequent harvests.

The data on plant height, number of tillers per clump and biomass yield above the ground level were recorded at the time of each harvest. The green phytomass was weighed and recorded as biomass yield. Essential oil concentration (%) in the plant was estimated by hydro-distillation method using Clevenger's apparatus. A sample of about 300 g of herb was harvested and hydro-distilled in a Clevenger's apparatus for 3 hours. Moisture in oil samples were removed by sodium sulphate anhydrous 2%. The oil concentration in plants was expressed as percentage on a volume basis (ml oil obtained from 100 g of biomass). The essential oil yield was computed by multiplying biomass yield with essential oil concentration (%) and expressed in kg ha^{-1} (Rao, 2001). The pooled data of the two year crop cycles 2013-15 and 2014-16 subjected were subjected to statistical analysis following analysis of variance (ANOVA) for the qualitative and quantitative characters (Cocharan and Cox, 1959) and presented harvest wise.

Results and Discussion

Growth attributes

Plant height of palmarosa was not significantly influenced by different date of planting, nitrogen level and planting geometries at each harvest during two year crop cycles (Table 1). Different planting geometries did not show significant effect on plant height of patchouli at harvest stage (Singh, 2008). While differences in plant height due to nitrogen levels were significant during the first and second harvest years. Maximum plant height was observed with 150 kg N ha^{-1} which was statistically at par with 100 kg N ha^{-1}. Higher plant height with application of 100 kg N ha^{-1} year^{-1} has also been reported in Palmarosa (Takankhar *et al.*, 2008).

Table.1 Plant height and number of tillers clump^{-1} of palmarosa (*Cymbopogon martinii*) as influenced by various date of planting, nitrogen application and planting geometries during the years 2013-15 and 2014-16 (pooled data of two year crop cycles)

Treatments	Plant height (cm)						No. of tillers clump^{-1}					
	1st year			2nd year			1st year			2nd year		
	1st harvest	2nd harvest	3rd harvest	1st harvest	2nd harvest	3rd harvest	1st harvest	2nd harvest	3rd harvest	1st harvest	2nd harvest	3rd harvest
Planting date												
April 25	141.47	144.75	145.17	147.92	145.30	147.19	50.69	65.12	69.91	73.78	74.98	76.21
May 10	136.75	139.80	142.73	145.27	143.39	142.42	47.07	58.13	60.58	63.83	64.10	64.66
May 25	134.47	137.87	141.59	143.56	140.21	140.74	45.84	53.27	53.37	58.53	56.95	57.45
CD at 5%	NS	NS	NS	NS	NS	NS	2.59	5.82	8.97	9.20	8.45	9.99
SEm±	3.13	3.63	4.13	3.71	3.28	3.44	0.66	1.49	2.30	2.36	2.16	2.56
Nitrogen level												
50 kg ha^{-1}	129.40	131.42	136.21	138.92	136.43	134.49	42.51	49.14	54.48	57.62	55.94	57.06
100 kg ha^{-1}	139.66	144.23	145.56	148.11	145.55	147.04	49.22	61.63	63.23	66.98	67.11	67.68
150 kg ha^{-1}	143.63	146.78	147.71	149.72	146.92	148.84	51.85	65.75	66.16	71.54	72.97	73.57
CD at 5%	8.28	7.96	7.64	8.15	8.28	8.45	5.83	10.13	6.69	8.26	9.16	8.46
SEm±	2.69	2.58	2.48	2.65	2.69	2.74	1.89	3.29	2.17	2.68	2.97	2.75
Planting geometry												
60cm×30cm	133.99	140.40	144.21	147.38	145.61	143.34	40.24	51.21	54.50	57.76	56.56	57.52
60cm×45cm	138.53	139.83	141.79	143.49	139.94	142.47	49.16	60.54	62.85	67.15	66.84	67.85
60cm×60cm	140.16	142.20	143.49	145.87	143.35	144.55	54.19	64.77	66.51	71.23	72.62	72.95
CD at 5%	NS	NS	NS	NS	NS	NS	7.06	7.67	6.60	6.40	8.44	9.07
SEm±	4.66	1.86	3.27	3.50	3.12	1.83	2.46	2.68	2.30	2.23	2.94	3.16

Table.2 Influence of date of planting, nitrogen application and planting geometries on biomass yield of palmarosa (*Cymbopogon martinii*) during the years 2013-15 and 2014-16 (pooled data of two years)

Treatments	Biomass yield (t ha^{-1})					
	1st Year			2nd Year		
	1st harvest	2nd harvest	3rd harvest	1st harvest	2nd harvest	3rd harvest
Planting date						
April 25	6.01	7.63	9.20	9.95	10.50	10.60
May 10	4.34	5.82	7.31	8.26	8.70	8.68
May 25	3.89	4.78	6.54	6.95	7.64	7.72
CD at 5%	1.34	1.45	1.55	1.41	1.40	1.73
SEm±	0.34	0.37	0.40	0.36	0.36	0.44
Nitrogen level						
50 kg ha^{-1}	3.36	4.21	5.84	5.99	6.84	7.02
100 kg ha^{-1}	5.07	6.69	8.20	8.80	9.67	9.67
150 kg ha^{-1}	5.80	7.33	9.01	10.36	10.34	10.31
CD at 5%	1.26	1.22	1.37	2.21	1.58	1.14
SEm±	0.41	0.40	0.44	0.72	0.51	0.37
Planting geometry						
60cm×30cm	5.99	7.61	8.54	9.87	10.74	10.57
60cm×45cm	4.30	5.83	7.45	7.94	8.66	8.81
60cm×60cm	3.94	4.79	7.06	7.32	7.44	7.62
CD at 5%	1.48	1.62	0.88	1.76	1.54	1.60
SEm±	0.52	0.56	0.31	0.61	0.54	0.59

Table.3 Influence of date of planting, nitrogen application and planting geometries on oil content (%) and essential oil yield (kg ha^{-1}) of palmarosa (*Cymbopogon martinii*) during the years 2013-15 and 2014-16 (pooled data of two years)

Treatments	Essential oil content (%)						Essential oil yield (kg ha^{-1})					
	1st year			2nd year			1st year			2nd year		
	1st harvest	2nd harvest	3rd harvest	1st harvest	2nd harvest	3rd harvest	1st harvest	2nd harvest	3rd harvest	1st harvest	2nd harvest	3rd harvest
Planting date												
April 25	0.59	0.61	0.65	0.65	0.67	0.67	34.36	46.12	59.84	64.93	70.40	71.70
May 10	0.57	0.60	0.65	0.64	0.66	0.66	24.72	34.90	47.32	53.48	57.48	57.75
May 25	0.58	0.59	0.63	0.64	0.65	0.67	21.84	29.38	41.38	44.36	49.94	51.76
CD at 5%	NS	NS	NS	NS	NS	NS	8.26	9.57	8.07	8.50	9.78	11.59
SEm±	0.01	0.02	0.02	0.01	0.01	0.01	2.12	2.45	2.07	2.18	2.51	2.97
Nitrogen level												
50 kg ha^{-1}	0.58	0.59	0.63	0.63	0.66	0.66	18.73	24.74	36.33	37.57	44.94	46.27
100 kg ha^{-1}	0.57	0.60	0.65	0.65	0.66	0.67	28.88	40.47	53.25	57.33	64.03	64.87
150 kg ha^{-1}	0.58	0.60	0.65	0.65	0.66	0.68	33.31	45.20	58.96	67.87	68.86	70.07
CD at 5%	NS	NS	NS	NS	NS	NS	7.64	7.74	10.09	12.99	10.45	7.80
SEm±	0.01	0.02	0.02	0.01	0.01	0.01	2.48	2.51	3.28	4.22	3.39	2.53
Planting geometry												
60cm×30cm	0.58	0.60	0.65	0.64	0.66	0.68	34.78	47.07	55.92	63.09	71.03	71.45
60cm×45cm	0.58	0.60	0.64	0.65	0.66	0.67	24.16	34.98	47.62	52.52	57.44	58.92
60cm×60cm	0.57	0.59	0.64	0.64	0.66	0.66	21.98	28.36	44.99	47.16	49.36	50.85
CD at 5%	NS	NS	NS	NS	NS	NS	8.66	10.08	5.73	11.91	10.59	10.38
SEm±	0.01	0.02	0.01	0.01	0.01	0.01	3.02	3.51	2.00	4.15	3.69	3.62

However, the differences in number of tillers clump^{-1} of palmarosa due to different date of planting, nitrogen levels and planting geometries were influenced significantly at each harvest during two year crop cycles (Table 1). The maximum number of tillers clump^{-1} was observed at April 25, which was significantly higher than that of May 10 and May 25. The highest number of tillers clump^{-1} was obtained with 150 kg N ha^{-1}. Virtually there was no difference in number of tillers clump^{-1} in the crop raised with 100 kg N ha^{-1} and 150 kg N ha^{-1}. Also, Takankhar *et al.*, 24 investigated that application of 100 kg N ha^{-1} year^{-1} produced significantly higher number of tillers per plant of palmarosa. Among planting geometries, the maximum number of tillers clump^{-1} was produced by planting geometries of 60 cm×60 cm in each harvest, which was statistically at par with 60 cm×45 cm and both of these treatments proved significantly superior to 60 cm×30 cm planting geometry. The lowest number of tillers clump^{-1} was observed in 60 cm×30 cm, which may be attributed to the fact that there was more number of plants under this treatment. Planting geometry with more space produced significantly more number of tillers than that of all the other planting geometries in palmarosa (Maheshwari *et al.*, 1991).

Biomass yield, oil content and essential oil yield

Significant variations in date of planting, nitrogen levels and planting geometries were recorded with respect to biomass yield (Table 2) and essential oil yield (Table 3) at each harvest during two year crop cycles. Significantly the highest biomass yield and essential oil yield were recorded in April 25 which was significantly higher than May 10 and May 25 at each harvest during two year crop cycles. Significantly higher yields of herb and essential oil were noticed in different dates of planting of cymbopogan (Singh *et al.*, 2000). The yield differences in biomass yield of palmarosa (Table 2) and essential oil yield (Table 3) between levels of nitrogen were significant during both the harvest years. The highest biomass yield and essential oil yield were attained with 150 kg N ha^{-1}, which was statistically at par with 100 kg N ha^{-1}. The lowest biomass yield was obtained with 50 kg N ha^{-1}. Shrama *et al.*, 1980 and Yadav *et al.*, 1984 observed that there was significantly linear response to Nitrogen upto 150 kg N ha^{-1} and found that the application of 150 kg ha^{-1} resulted in high total biomass and essential oil yield in palmarosa. While, Khode *et al.*, (1999) concluded that the 100 kg N ha^{-1} has significantly increased biomass and oil yield of palmarosa than lower N rates. The maximum biomass yield can be attributed to the favourable influence of nitrogen on plant height, tiller production which favours biomass yield of palmarosa (Singh and Sharma, 2001; Takankhar *et al.*, 2008).

Among different planting geometries, the highest pooled biomass yield (Table 2) and essential oil yield (Table 3) of two year crop cycles were observed in planting geometries 60 cm×30 cm, which was significantly superior to 60 cm×45 cm and 60 cm×60 cm. This was due to the reason that the number of plants in 60cm×30 cm was more than other spacing treatments. Maximum oil yield of palmarosa was obtained at 60 cm × 30 cm spacing (Khode *et al.*, 1999). Some other studies emphasized closer spacings for obtaining higher yields of aromatic crops in Assam, Bangalore, Hyderabad, Delhi, Kerala and Punjab (Singh *et al.*, 2000). Rao *et al.*, 1990 also obtained higher biomass yield and essential oil yield with closer spacing than wider spacing due to more number of plants per unit area.

The date of planting, land configuration and planting geometries resulted in non-significant values of oil content of palmarosa at both harvests during both the year of crop cycle (Table 3). The planting date did not influence oil content (Singh *et al.*, 1991). Neither plant spacing nor nitrogen rate had any effect on the essential oil concentration in palmarosa (Rao *et al.*, 1990)

Based on pooled data on two year crop cycle, it may be concluded that the highest biomass yield and essential oil yield were recorded in April 25 which obtained higher biomass yield and essential oil yield than May 10 and May 25 at each harvest during both the years of crop cycles. Also, higher biomass yield and essential oil yield were recorded in crop raised with 150 kg N ha^{-1} which was statistically at par with 100 kg N ha^{-1} during each harvest of palmarosa. Among planting geometries, the highest biomass yield and essential oil yield were observed in planting geometries 60cm×30cm, which were significantly superior to 60cm×60cm and 60cm×45cm. Further, date of planting, nitrogen application and planting geometries did not cause significant variation in the oil concentration.

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