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Effect of date of planting, nitrogen application and planting geometries on growth, herbage yield and essential yield of lemon grass (*Cymbopogan flexuosus* Stapf.) under sub-mountaineous region of Punjab

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ABSTRACT

A field experiment was conducted at Punjab Agricultural University, Regional Research Station, Gurdaspur during two year crop cycles of 2013-15 and 2014-16 to find out the effect of date of planting, nitrogen application and planting geometries on the fresh herbage yield and essential oil yield of lemon grass under sub-mountaineous region of Punjab. The experiment was laid out in split-split plot design having three replications with three planting dates of lemon grass viz. March 20, April 5and April 20 in main plots, three nitrogen levels (50, 100 and150 kg ha^{-1}) in sub-plots and three planting geometries viz 60×45 cm, 60×30 cm and 45×45 cm in sub-sub plots. The highest herbage yield and essential oil yield were recorded in March 20 which was statistically at par with April 5 and these treatments obtained higher herbage yield and essential oil yield than April 20 at each harvest during both the years of crop cycles. Also, higher fresh herbage 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 lemon grass. Among planting geometries, the highest fresh herbage yield and essential oil yield was observed in planting geometries 60×30cm, which was statistically at par with 45×45 cm and proved significantly superior to 60×45cm. Further, date of planting, nitrogen application and planting geometries did not cause significant variation in the oil concentration.

***Keywords*:** Date of planting, essential oil, herbage yield, lemon grass, nitrogen and planting geometries

Lemon grass (*Cymbopogan flexuosus* Stapf.) is a tall, fast growing, multiharvest, perennial aromatic grass belonging to family poaceae. It has stout and erect culm upto 1.5-2 m height. Leaves are long, glaucoces, green, linear tapering upwards and along the margins, ligule very short. The freshly harvested biomass of lemon grass on hydro-distillation yields an essential oil, lemon grass oil, which is widely used in perfumery, confectionery, beverage industries. Lemon grass oil is rich in active ingredient *i.e*. citral (75-80%) (Gupta and Sharma, 2009; Joy *et al*., 2001), geraniol, geranyl acetate, monoterpene, olefins, limonene *etc*. (Weiss, 1997). The essential oil of lemon grass has strong lemon like odour which enabled it to be used in all the products where a lemon flavour is preferred. Also, the characteristic smell of oil makes its use in scenting of soaps, detergents and an array of other products extracted from the oil. Besides, perfumery value, it is also used as a starting material for manufacturing of ionone's, which produces Vitamin-A (Rangari *et al*., 2009). Also, it is used in herbal tea (Hussain, 1995), to remedy digestive problems, diarrohea and stomach ache and considered as carminative (Carlin *et al*., 1986). The essential oil of lemon grass is used in aromatherapy too (Rande *et al*., 1959). Also, the various components of this essential oil possess antimicrobial, antifungal, anti-bacterial (Pattnaik *et al*., 1990) and mosquito repellent preparations properties (Schanbeng and Khan, 2002). Also, it has many other uses like a medicine to treat various health ailments including acne, athletic's foot, flatulence, muscle aches and scabies and has a great wound healing effect. It is also used as remedy for coughs, elephantiasis flu, gingivitis, headache, leprosy, opthalmia, pneumonia and vascular disorders.The spent of lemongrass is suitable for making paper, source of manure and also used as fuel for the distillation of the grass. Most of the species of lemon grass are native to South Asia, South East Asia and Australia. It was grown in India a century back and is now commercially cultivated in different parts *viz*., along western Ghats, Karnataka and Tamil Nadu, foothills of Arunachal Pradesh and Sikkim (Qadry, 2008-09). It is estimated that annual world production of lemon grass oil is around 1000 tonnes from an area of 16,000 ha (Joy *et al*., 2006) while it is grown in India in about 3,000 ha area with annual production ranges between 300-350 t annum^{-1} (Evans and Trease, 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 Beemnet *et al*. (2011) in lemon grass. Being a foliage rich crop, it

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responded well to fertilizer nitrogen application (Singh and Singh, 1992). Fertilizer applications, specially nitrogenized ones, affect the yield of essential oils by the increase of the production of total bio-mass per unit of area (Sangwan *et al*., 2001). 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 examine the effect of date of planting, nitrogen and planting geometries on growth, herbage and essential oil yield of lemon grass (*Cymbopogan flexuosus* Stapf.) under sub-mountaineous 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-mountaineous 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 nitrogen on the basis of organic carbon (0.54%), medium in available P_2O_5 (19.0 kg ha^{-1}) and low in K_2O (87.5 kg ha^{-1}) at 0-15 cm soil depth. The soil was neutral in reaction (pH-7.1) with normal electric conductivity (0.24 ds m^{-1}). The experiment was laid out in split-split plot design having three replications with date of planting of lemon grass in main plots, nitrogen levels in sub-plots and planting geometries in sub-sub plots. It consists of three planting dates of lemon grass plot *viz*. March 20, April 5 and 20, three nitrogen levels (50, 100 and 150 kg ha^{-1}) in sub-plots and three planting geometries (60×45cm, 60×30cm and 45 ×45 cm) in sub-sub plots during two year crop cycles.

The lemon grass cultivar 'Krishna' was grown by slips obtained by dividing well-grown clumps. For planting of slips, clumps were trimmed from 20-25 cm above ground, divided into slips and the lower brown sheath was removed to expose young roots. Slips were planted at a suitable depth to cover the root zone properly without injuring the roots. The field was thoroughly ploughed and levelled. Slips were planted according to the date of planting, fertilized as per treatments of respective level of nitrogen with different planting geometry treatments.

The lemon grass crop was fertilized with 30 kg P_2O_5 ha^{-1} and 40 kg K ha^{-1} (Maiti *et al.*, 2006) 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 at the time of planting (Singh and Singh, 1992). The crop was irrigated immediately after plantation for better establishment of the crop, subsequently once in a week and thereafter as and when required. 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. 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 with sickle at 15 cm above the ground level. The data on plant height, Number of tillers per clump and fresh herbage yield above the ground level were recorded at the time of each harvest. Oil concentration (%) in fresh herbage was estimated by hydro-distillation method using Clevenger's apparatus (Cassel *et al*., 2009). 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 fresh herbage). The essential oil yield was computed by multiplying the oil concentration (%) with that of herbage yield and expressed in kg ha^{-1} (Gajbhiye *et al.*, 2013). The data of the two year crop cycles 2013-15 and 2014-16 were pooled and analysed statistically using 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 lemon grass 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 due to higher level of Nitrogen has also been reported in lemon grass (Singh *et al*., 2008).

However, the differences in number of tillers $clump^{-1}$ of lemon grass 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 March 20, which was statistically at par with April 5 and both these levels were significantly higher than that of April 20. The highest number of tillers $clump^{-1}$ were obtained with 150 kg N ha^{-1}. Virtually there was no difference in number of tillers $clump^{-1}$ in the crop

Table 1: Plant height and number of tillers clump^{-1} of lemon grass during the years 2013-15 and 2014-16 (pooled)

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												
March 20	104.59	104.79	106.44	105.51	104.27	105.99	55.95	74.76	80.63	81.43	86.85	90.99
April 5	102.93	102.39	104.20	102.96	102.83	103.40	54.20	69.60	75.78	78.37	82.37	86.09
April 20	101.70	100.33	103.12	101.60	100.09	102.04	50.13	59.36	64.62	67.05	70.40	73.89
SEm (±)	**2.81**	**3.41**	**4.06**	**4.11**	**3.78**	**3.45**	**0.89**	**2.34**	**2.61**	**2.46**	**1.81**	**2.31**
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**3.48**	**9.14**	**10.18**	**9.62**	**7.08**	**9.02**
Nitrogen level												
50 kg ha^{-1}	96.73	96.52	98.61	96.37	96.08	96.87	48.35	56.77	67.02	66.99	69.33	75.10
100 kg ha^{-1}	105.59	104.63	106.53	106.30	104.79	106.65	55.72	71.62	75.47	77.98	82.60	86.10
150 kg ha^{-1}	106.91	106.36	108.62	107.40	106.31	107.90	56.21	75.34	78.54	81.87	87.70	89.76
SEm (±)	**2.17**	**2.34**	**2.43**	**2.59**	**2.52**	**2.39**	**1.58**	**3.52**	**2.28**	**3.10**	**2.08**	**2.26**
LSD (0.05)	**6.67**	**7.22**	**7.49**	**7.99**	**7.78**	**7.37**	**4.87**	**10.85**	**7.03**	**9.53**	**6.40**	**6.95**
Planting geometries												
60×45 cm	103.59	104.04	105.40	104.59	104.35	105.42	58.20	72.60	77.91	80.13	87.14	88.72
60×30 cm	102.14	100.99	103.38	101.77	100.20	102.07	48.33	62.49	68.92	70.87	72.35	78.51
45×45 cm	103.48	102.48	104.98	103.71	102.63	103.93	53.76	68.64	74.20	75.84	80.13	83.73
SEm (±)	**2.46**	**3.05**	**3.10**	**3.55**	**2.90**	**3.22**	**2.52**	**2.74**	**2.38**	**2.13**	**3.10**	**1.87**
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**7.23**	**7.86**	**6.82**	**6.11**	**8.89**	**5.36**

Table 2: Effect of date of planting, nitrogen application and planting geometries on fresh herbage yield of lemon grass during the years 2013-15 and 2014-16 (pooled)

Treatments	Fresh herbage yield (t ha^{1})					
	1st Year			2nd Year		
	1st harvest	2nd harvest	3rd harvest	1st harvest	2nd harvest	3rd harvest
Planting date						
March 20	6.95	9.59	10.44	10.69	11.11	11.76
April 5	6.67	8.80	9.60	9.76	10.63	11.41
April 20	5.26	6.36	8.03	8.21	8.72	9.60
SEm (±)	**0.29**	**0.37**	**0.33**	**0.34**	**0.45**	**0.37**
LSD (0.05)	**1.13**	**1.43**	**1.29**	**1.31**	**1.74**	**1.42**
Nitrogen level						
50 kg ha^{-1}	5.32	6.85	7.49	7.25	8.51	9.53
100 kg ha^{-1}	6.62	8.74	9.93	10.31	10.52	11.07
150 kg ha^{-1}	6.94	9.15	10.65	11.11	11.43	12.17
SEm (±)	**0.35**	**0.25**	**0.60**	**0.62**	**0.37**	**0.42**
LSD (0.05)	**1.06**	**0.76**	**1.85**	**1.90**	**1.14**	**1.30**
Planting geometries						
60×45 cm	5.28	7.09	7.61	7.85	9.07	9.68
60×30 cm	7.07	9.21	10.89	11.13	11.09	12.02
45×45 cm	6.53	8.44	9.57	9.69	10.31	11.08
SEm (±)	**0.39**	**0.35**	**0.54**	**0.59**	**0.29**	**0.40**
LSD (0.05)	**1.12**	**1.01**	**1.56**	**1.68**	**0.82**	**1.13**

raised with 100 kg N ha^{-1} and 150 kg N ha^{-1}. Singh and Singh, 1998 also observed favourable effect on number of tillers clump^{-1} with 100 kg N ha^{-1}. Among planting geometries, the maximum number of tillers clump^{-1} was produced by planting geometries of 60 ×45 cm in each harvest, which was statistically at par with 45 ×45 cm. The lowest number of tillers clump^{-1} were observed in 60 ×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).

Herbage yield, oil content and essential oil yield

Significant variations in date of planting, nitrogen levels and planting geometries were recorded with respect to herbage yield (Table 2) and essential oil yield (Table 3) at each harvest during two year crop cycles. Significantly the highest herbage yield and essential oil yield were recorded in March 20 which was statistically at par with April 5 and these treatments obtained significantly higher herbage yield and essential oil yield than April 20 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 fresh herbage yield of lemon grass (Table 2) and essential oil yield (Table 3) between levels of nitrogen were significant during both the harvest years. The highest herbage yield and essential oil yield was attained with 150 kg N ha^{-1}, which was statistically at par with 100 kg N ha^{-1}. The lowest herbage yield was obtained with 50 kg N ha^{-1}. Singh and Singh, 1998 concluded that the 100 kg N ha^{-1} has significantly increased the herb and oil yield of lemon grass over control. The maximum herbage yield can be attributed to the favourable influence of nitrogen on plant height, tiller production which favours herbage yield of lemon grass (Marschner, 1999). Applications of 150 kg N ha^{-1} resulted in higher herb yield and oil yield (Singh *et al.*, 2008).

Among different planting geometries, the highest pooled fresh herbage yield (Table 2) and essential oil yield (Table 3) of two year crop cycles were observed in planting geometries 60×30 cm, which was statistically at par with 45×45 cm and proved significantly superior to 60×45 cm. This was due to the reason that the number of plants in 60×30 cm was more than other spacing

Table 3: Effect of date of planting, nitrogen application and planting geometries on oil content and essential oil yield in lemon grass during the years 2013-15 and 2014-16 (pooled)

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												
March 20	0.51	0.54	0.54	0.56	0.57	0.60	36.02	51.71	57.34	58.52	63.31	70.84
April 5	0.51	0.52	0.54	0.56	0.56	0.59	33.85	46.10	52.35	54.55	59.65	67.57
April 20	0.51	0.52	0.53	0.54	0.55	0.59	26.98	33.25	42.96	44.62	47.91	56.68
SEm (±)	**0.01**	**0.01**	**0.01**	**0.02**	**0.01**	**0.01**	**1.25**	**2.13**	**1.97**	**1.71**	**2.48**	**2.39**
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**4.88**	**8.31**	**7.69**	**6.68**	**9.68**	**9.34**
Nitrogen level												
50 kg ha^{-1}	0.50	0.53	0.52	0.53	0.56	0.60	26.70	36.14	39.98	38.53	47.20	56.96
100 kg ha^{-1}	0.52	0.53	0.54	0.57	0.56	0.59	34.75	46.55	54.37	57.62	59.38	65.81
150 kg ha^{-1}	0.51	0.53	0.55	0.56	0.57	0.60	35.40	48.37	58.29	61.53	64.30	72.32
SEm (±)	**0.01**	**0.01**	**0.01**	**0.02**	**0.01**	**0.01**	**2.22**	**1.26**	**3.39**	**2.37**	**2.08**	**2.44**
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**6.84**	**3.89**	**10.43**	**7.30**	**6.40**	**7.52**
Planting geometries												
60×45 cm	0.50	0.53	0.52	0.55	0.56	0.59	26.27	37.58	40.56	43.60	50.74	57.28
60×30 cm	0.50	0.52	0.55	0.55	0.56	0.59	35.57	48.34	60.23	60.60	61.90	71.66
45×45 cm	0.53	0.53	0.54	0.56	0.57	0.60	35.00	45.14	51.85	53.48	58.22	66.15
SEm (±)	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**2.25**	**1.83**	**3.06**	**2.83**	**1.69**	**2.54**
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**6.47**	**5.26**	**8.78**	**8.12**	**4.84**	**7.28**

treatments. Maximum oil yield was obtained at 60× 30 cm spacing (Yadav *et al.,* 1984). Some other studies emphasized closer spacings for obtaining higher yields in Assam, Bangalore, Hyderabad, Delhi, Kerala and Punjab (Singh *et al*., 2000). Singh *et al*. (2008) also obtained higher herbage 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 lemon grass at both harvests during both the year of crop cycle (Table 3). The planting date did not influence oil content (Singh *et al*., 1991). The oil content and quality of essential oil of lemon grass remained unaffected both by nitrogen application and plant spacing (Singh *et al.,* 2008).

Based on pooled data on two year crop cycle, it may be concluded that the highest herbage yield and essential oil yield of lemon grass were recorded in March 20 which was statistically at par with April 5 and these treatments obtained higher herbage yield and essential oil yield than April 20 at each harvest during both the years of crop cycles. Also, higher fresh herbage 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 both each harvest of lemon grass. Among planting geometries, the highest fresh herbage yield and essential oil yield were observed in planting geometries 60×30cm, which was statistically at par with 45×45 cm and proved significantly superior to 60×45cm. Further, date of planting, nitrogen application and planting geometries did not cause significant variation in the oil concentration of lemon grass.

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