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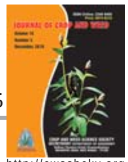

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Effect of planting time, nitrogen application and planting geometries on growth and yield of citronella (*Cymbopogon winterianus* Jowitt.) under sub-mountaineous region of Punjab

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ABSTRACT

A field experiment was conducted at Punjab Agricultural University, Regional Research Station, Gurdaspur during two year crop cycles of 2013-14 and 2014-15 to find out the effect of date of planting, nitrogen application and planting geometries on the fresh herbage yield and essential oil yield of citronella under sub-mountaineous region of Punjab. The experiment was laid out in split-split plot design having three replications with three planting dates of citronella viz. September 30, October 15, October 30 in main plots, three nitrogen levels (50, 100 and 150 kg ha^{-1}) in sub-plots and three planting geometries viz. 60 ×45cm, 60×30cm, 45×45cm in sub-sub plots. The highest herbage yield and essential oil yield were recorded in October 30 which was statistically at par with October 15 and these treatments obtained higher herbage yield and essential oil yield than September 30 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 citronella. Among planting geometries, the highest fresh herbage yield and essential oil yield was observed in planting geometries of 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: Citronella, date of planting, essential oil, herbage yield, nitrogen and crop geometries

Citronella (*Cymbopogon winterianus* Jowitt.) is a foliage rich, multi-cut, perennial aromatic grass belonging to family Poaceae. It is having fibrous roots, tufted culms over 2 m tall with smooth and shiny leaves which are glabrous at the nodes. The leaf blades are linear, gradually tapering to long, drooping two-third of their length. The freshly harvested biomass on hydro distillation yields an essential oil, the citronella oil, which is the natural source of important perfumery chemicals like citronellal, geraniol and hydroxyl citronellol (Wany *et al*., 2013) and most commonly a blend of other high perfumery bases *viz*. monoterpenes, monoterpenoids, and phenylpropanoids containing chiefly limonene, linalool, geraniol, elemol, geranyl acetate, á-bisafalol, etc. (Cassel *et al*., 2009). Citronella is considered to be a native of tropical Asia and is cultivated in Africa and America also (Shasney *et al.*, 2000). It is estimated that the total production of citronella is around 4,000 tonnes in the world with China and Indonesia representing a 40 per cent share of this volume (Lawrence, 2009). It was first introduced in India in 1959 from Indonesia (Java island) (Kaul *et al.*, 1997). In India, production of citronella oil is 300-350 t per annum in the the states of Assam, Karnatka, Uttar Pradesh, Madhya Pradesh, Maharashtra, Tamil nadu and West Bengal (Katiyar *et al*., 2011).

Citronella oil has powerful, lemon like odour and subtle citrus flavour. The oil is used for perfuming soaps, detergents, cosmetics and *agarbattis*. It is commonly known for its natural insect repellent properties and is used for making mosquito repellent creams, used in a nebulising or humidifying diffuser. As far as therapeutic use of Citronella oil is concerned, most of the activities are confined to mosquito repellent, anti-parasitic, nematicidal, anti-fungal and anti-bacterial agents. Citronella oil repels insects such as mosquitoes, black flies, fleas and ticks, therefore, preventing its bites. Essential oil of Citronella plays an important role in improving human health due to their potential of bioactive components which act as anti-inflammatory, antioxidant, anticancer, anticonvulsant agents and central nervous system (CNS) disorders (Quintans-Junior *et al.*, 2008). Traditionally, it was used for treatment of fever, intestinal parasites, digestive and menstrual problems. It is used for rheumatic pain in Chinese medicine. It has many uses in aromatherapy. It can be used as massage oil for aching joints and muscles (Katiyar *et al*., 2011). Citronella oil has a number of different but diverse therapeutic properties. It is antiseptic, bactericidal and a deodorant. It is also used as a diaphoretic, an insecticide, a tonic and a stimulant. Even citronella oil-possesses antifungal properties against several species of *Aspergillus*, *Penicillium* and *Eurotium* due to presence of citronellal and linalool, components of citronella oil, has also been reported (Wany *et al.*, 2013).

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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 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 study the effect of date of planting, nitrogen and planting geometries on growth, herbage and essential oil yield of citronella (*C. winterianus*) 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°32′ 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 (0.54%), medium in available P_2O_5 (19.0 kg ha^{-1}) and low in K_2O (87 kg ha^{-1}) at 0-15 cm soil depth. The soil was neutral in reaction (pH-7.0) 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 citronella in main plots, nitrogen levels in sub-plots and planting geometries in sub-sub plots. It consists of three planting dates of citronella plot *viz*. September 30, October 15 and October 30, three nitrogen levels (50, 100 and 150 kg ha^{-1}) in sub-plots and three planting geometries (60×45cm, 60×30cm, 45 ×45 cm) in sub-sub plots during during two year crop cycles.

The citronella cultivar 'Java' 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 citronella crop was fertilized with 40 kg P_2O_5 ha^{-1} and 40 kg K ha^{-1} (Singh *et al.*, 1994) 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 clump^{-1} 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} (Dhar *et al*., 1996). 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 citronella 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 Java citronella (Rao *et al*., 1985).

Table 1: Effect of planting time, N- application and planting geometries on growth attributes of citronella during 2013-15 and 2014-16

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												
September 30	100.93	102.78	103.36	101.95	101.64	102.90	42.48	43.59	57.01	62.99	65.57	63.92
October 15	99.91	102.56	101.58	101.13	99.57	102.13	49.20	56.11	71.48	76.09	77.33	77.21
October 30	99.16	101.86	100.89	100.60	98.93	101.53	50.90	60.08	75.06	80.56	80.65	83.14
SEm (±)	**3.03**	**4.08**	**2.10**	**1.79**	**3.00**	**4.06**	**1.50**	**2.93**	**3.04**	**3.10**	**2.48**	**2.74**
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**5.89**	**11.46**	**11.86**	**12.11**	**9.66**	**10.68**
Nitrogen level												
50 kg ha^{-1}	93.86	95.98	95.79	94.77	93.83	95.52	42.28	41.51	60.90	64.44	64.34	63.24
100 kg ha^{-1}	101.71	104.58	104.13	103.05	102.59	104.71	48.90	57.09	69.84	75.99	77.21	78.63
150 kg ha^{-1}	104.42	106.64	105.91	105.85	103.71	106.32	51.40	61.17	72.81	79.21	82.00	82.40
SEm (±)	**2.47**	**2.63**	**2.61**	**2.26**	**2.46**	**2.30**	**1.61**	**3.45**	**2.55**	**2.78**	**3.70**	**3.39**
LSD (0.05)	**7.60**	**8.11**	**8.04**	**6.97**	**7.57**	**7.09**	**5.21**	**10.63**	**7.87**	**8.56**	**11.41**	**10.43**
Spacing (cm)												
60×45	102.17	104.11	103.46	102.30	100.58	103.92	52.66	58.76	73.34	78.33	80.81	80.32
60×30	97.35	100.50	100.42	99.98	98.86	100.46	42.41	47.74	61.82	68.22	67.06	68.90
45×45	100.47	102.60	101.95	101.40	100.70	102.17	47.52	53.29	68.39	73.10	75.68	75.06
SEm (±)	**3.40**	**3.19**	**3.55**	**3.83**	**2.70**	**3.06**	**2.54**	**2.38**	**3.01**	**2.38**	**3.50**	**2.34**
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**7.29**	**6.82**	**8.62**	**6.82**	**10.04**	**6.73**

Table 2: Effect of planting time, nitrogen application and planting geometries on yield of citronella during 2013-15 and 2014-16

Treatments	Citronella herb yield (t ha^{-1})					
	1st Year			2nd Year		
	1st harvest	2nd harvest	3rd harvest	1st harvest	2nd harvest	3rd harvest
Planting date						
September 30	3.41	3.88	5.60	6.68	6.85	7.75
October 15	4.84	5.22	7.06	8.55	8.99	9.89
October 30	5.24	6.10	7.59	9.63	9.92	10.24
SEm (±)	**0.30**	**0.29**	**0.28**	**0.37**	**0.48**	**0.46**
LSD (0.05)	**1.17**	**1.14**	**1.08**	**1.43**	**1.89**	**1.81**
Nitrogen level						
50 kg ha^{-1}	3.23	4.12	5.74	6.61	6.51	7.75
100 kg ha^{-1}	4.83	5.25	7.03	8.60	9.13	9.74
150 kg ha^{-1}	5.44	5.83	7.47	9.65	10.12	10.39
SEm (±)	**0.36**	**0.35**	**0.33**	**0.64**	**0.41**	**0.45**
LSD (0.05)	**1.11**	**1.07**	**1.01**	**1.65**	**1.26**	**1.38**
Spacing (cm)						
60×45	3.46	4.04	5.68	6.87	7.20	8.26
60×30	5.44	5.96	7.47	9.19	9.79	10.08
45×45	4.60	5.20	7.09	8.81	8.77	9.55
SEm (±)	**0.34**	**0.36**	**0.41**	**0.51**	**0.40**	**0.34**
LSD (0.05)	**0.99**	**1.05**	**1.18**	**1.45**	**1.15**	**0.96**

Table 3: Effect of planting time, N- application and planting geometries on oil yield of citronella during 2013-15 and 2014-16

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												
September 30	0.96	1.04	1.11	1.12	1.23	1.23	32.54	40.30	62.23	74.17	84.15	94.68
October 15	0.98	1.05	1.13	1.12	1.23	1.23	47.43	54.56	79.54	95.61	110.70	121.76
October 30	0.98	1.05	1.13	1.14	1.25	1.24	51.74	64.20	85.57	107.86	123.06	126.50
SEm (±)	**0.02**	**0.01**	**0.01**	**0.02**	**0.01**	**0.01**	**3.30**	**3.12**	**3.26**	**3.89**	**5.95**	**5.33**
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**12.89**	**12.18**	**12.71**	**15.18**	**23.23**	**20.81**
Nitrogen level												
50 kg ha^{-1}	0.96	1.04	1.11	1.12	1.23	1.23	31.01	42.71	63.76	73.31	79.98	95.38
100 kg ha^{-1}	0.99	1.05	1.13	1.13	1.24	1.23	47.37	55.00	79.60	96.13	112.76	119.05
150 kg ha^{-1}	0.98	1.05	1.13	1.13	1.25	1.24	53.32	61.36	83.99	108.18	125.17	128.52
SEm (±)	**0.02**	**0.01**	**0.01**	**0.02**	**0.01**	**0.004**	**3.23**	**3.61**	**3.79**	**4.95**	**5.05**	**5.47**
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**9.94**	**11.12**	**11.67**	**15.25**	**15.55**	**16.84**
Spacing (cm)												
60×45	0.96	1.04	1.10	1.13	1.24	1.23	33.55	42.15	63.07	77.44	88.74	101.22
60×30	0.99	1.05	1.13	1.12	1.24	1.23	53.23	62.29	84.49	102.06	120.90	124.19
45×45	0.97	1.05	1.13	1.13	1.24	1.23	44.92	54.62	79.78	98.13	108.27	117.54
SEm (±)	**0.02**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**3.44**	**3.83**	**4.63**	**5.27**	**4.89**	**4.17**
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**9.87**	**10.98**	**13.29**	**15.12**	**14.03**	**11.97**

However, the differences in number of tillers clump^{-1} of citronella 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 October 30, which was statistically at par with October 15 and both these levels were significantly higher than that of September 30. 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}. There was significant increase in number of tillers plant^{-1} of citronella due to nitrogen application from 0 to 200 kg N ha^{-1} has also been reported (Singh *et al*., 1998). Among planting geometries, the maximum number of tillers clump^{-1} was produced by planting geometries of 60×45cm in each harvest, which was statistically at par with 45 ×45 cm. The lowest number of tillers clump^{-1} was 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 October 30 which was statistically at par with October 15 and these treatments obtained significantly higher herbage yield and essential oil yield than September 30 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 citronella (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}. Rao *et al.* (1991) concluded that the 100 kg N ha^{-1} has significantly increased the herb and oil yield of Citronella 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 citronella (Rao *et al.,* 1985, Yadav *et al*., 1984). Khan and Narayan (1972) reported that Java citronella respond well to fertilizer application, particularly nitrogen and observed high oil yield and monetary returns with application of 100 kg N ha^{-1} (as urea in six splits).

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 60×30cm was more than other spacing treatments. Maximum oil yield was obtained at 60 × 30 cm spacing (Yadav *et al.*, 1984). Some other studies emphasized closer spacing for obtaining higher yields in Assam, Bangalore, Hyderabad, Delhi, Kerala and Punjab (Singh *et al*., 2000). Dhar *et al*. (1996) 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 citronella at both harvests during both the year of crop cycle (Table 3). The planting date did not influence oil content (Singh *et al*., 1991). Content and quality of essential oil of citronella remained unaffected both by nitrogen application and plant spacing (Dhar *et al*., 1996).

Based on pooled data on two year crop cycle, it may be concluded that the highest herbage yield and essential oil yield were recorded in October 30 which was statistically at par with October 15 and these treatments obtained higher herbage yield and essential oil yield than September 30 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 citronella. 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.

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