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Different micro-environment condition on growth and yield of safflower (*Carthamus tinctorius* L.) in Prayagraj

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Abstract
A field experiment was conducted during kharif season 2018-2019 at the Forest Nursery and Research Centre, College of Forestry, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj study the "Effect on temperature and humidity and different sowing dates at growth and yield of safflower in Prayagraj condition". In India, amid 2018-2019 the world, safflower is grown in 7, 52,000 ha with a total production of 6, 46,000 tons. India, Kazakhstan, Argentina, the United States and Mexico are leading producers of safflower grown for both seed and oil. India ranks first in Area (40%) and Production (29%) of the safflower grown across the world. In horticulture, heat units are regularly communicated as developing degree days (GDD). Now and then developing degree days are called developing degree units (GDU), however the two terms are indistinguishable. Ascertaining GDD for a particular day utilizes a basic equation that includes subtracting a base or limit temperature from the normal temperature through the afternoon. The base temperature is the limit temperature for which plant development starts. The soil of experimental plot was sandy loam in texture, nearly neutral in soil reaction (pH 6.0), low in organic carbon (0.35%), available N (230 kg ha^{-1}), available P (20 kg ha^{-1}) and available K (189 kg ha^{-1}). Experiment was laid out in Factorial Randomized Block Design with three levels of Nitrogen [(100 kg ha^{-1}), (120 kg ha^{-1}) and (140kg ha^{-1})] and three levels of Sulphur (20 kg ha^{-1}), (30 kg ha^{-1}) and (40 kg ha^{-1}). There were nine treatments each replicated three. The result showed that growth attributes *viz.,* Plant height (72.36cm) at 120 DAS, flowering (41.13) at 90 DAS and pod per plant (39.60g) at 90 DAS whereas yield attributes and yield *viz.,* Seed Germination (178.33), Test Weight (53.13), Pod per plant (39.600) and grain yield (34.76q/ha) was recorded highest with the application of 140 kg/ha and 40 kg/ha.

Keywords: Nitrogen, sulphur, GPS, GDS, safflower, agrometeological condition

Introduction
Safflower in English language and safran and batard in French, carthame in Spanish, cartamo in Latin, saflor in German, kusum in India and Pakistan and honghua in China (Lajevardi, 1980) [8]. Safflower seeds are used in food industry for the production of oil. Depending on the variety there are two kinds of oil: oil with a high content of linoleum acid, and oil with a high content of oleic acid. Safflower seeds are used both in the pharmaceutical industry, because of their therapeutic properties, and in varnish and paint industry (Brien, 2008) [13]. Safflower (*Carthamus tinctorius* L.) is a member of the family Compositae or Asteraceae (Weiss, 2000) [17], cultivated mainly for its seed, which is used as edible oil, birdseed or for its flowers, used as dye sources and medicinal purposes (Ekin, 2005; Dordas and Istanbulluoglu, 2009, Emongor, 2010) [4, 7, 5]. Flowers are also used in food industry as a spice and natural food colouring, being less expensive than saffron (Crocus sativus). In textile industry, flowers are used for their yellow, red, red-purple, olive and mustard, pigments and in pharmaceutical and cosmetic industry for their many therapeutic properties (Dajue and Mundel, 1996) [2]. Safflower is a temperate zone plant grown in arid and semi-arid regions of the world McPherson *et al*. 2004) [10]. Safflower oil is also now used as a diesel fuel substitute (Ogut and Oguz 2006) [14]. India is the largest producer of safflower (*Carthamus tinctorius* L.) that it accounts for 46% of the world production (421,000 tons) and uses it mainly in oil production (Rowland, 1993) [15]. FAO (2011) [6], safflower is produced in large areas in India (718,167 ha), Mexico (391,145 ha), Ethiopia (71,939 ha) and USA (175,000 ha, mainly in California, Nebraska, Arizona and Montana). Interest in cultivation of safflower has increased because of increased demand for vegetable oil for biodiesel and edible oil (Mailer *et al.* 2008) [9]. Safflower (*Carthamus tinctorius* L.) belongs to the family Asteraceae or Compositae. The genus Carthamus is comprised of 16 species and is a member of the subtribe Centraureinae, tribe Cardueae (thistles), subfamily Tubuliflorae (Vilatersana *et al.* 2000) [16].

The cultivated (*Carthamus tinctorius* L.) has a chromosome number of 2n = 24 (Zehra, 2005) [18]. Safflower is a branching, thistle-like herbaceous annual or winter annual plant, with numerous spines on leaves and bracts. Safflower plant can grow to a height of 30-210 cm tall with globular flower heads, bright yellow, orange or red flowers. It has a strong tap root that can grow to a depth of 2-3 m, enabling it to thrive under dry climates. Safflower is also grown in regions where rainfall is high and under greenhouse production as a cut flower or vegetable. Safflower is mainly grown in arid and semi-arid regions of the world as an oilseed crop, birdseed or for its flowers, used as dyes and for medicinal purposes (Emongor, 2010) [5]. Safflower leaves are eaten as vegetables (Weiss, 1983) and they are rich in carotene, riboflavin, vitamins A and C, iron, phosphorus and calcium (Nimbkar and Singh, 2006). Interest in cultivating safflower as source of edible oil has further been stimulated since the identification of safflower oil as a rich source of polyunsaturated essential fatty acid linoleic acid (70- 87%) and monounsaturated fatty acid oleic acid (11-80%) (Murthy and Anjani, 2008) [12]. High linoleic acid safflower oil has an important use in the paint industry. Safflower oil is preferred for the paint and varnish industry owing to its specific properties of absence of linolenic acid, presence of high linoleic acid, low colour values, nonyellowing, low free fatty acids, low unsaponifiables, and no wax, which make the quality in paints, alkyd resins, and coatings beyond comparison (Berglund *et al*., 2007) [1]. Safflower reaction to various water system routines assumes an essential job in safflower seed and oil yield. Reasonable water system routine expands seed yield essentially through its impact on the quantity of heads per plant and the expansion is more noteworthy in auxiliary branches. Keeping up of soil dampness at a sufficient dimension delivers more grain and oil yield in safflower (Mosallayi, 2011) [11]

Materials and Methods

The experiment was carried out during *Rabi* season 2018, at the Nursery reason farm of College of Forestry, SHUATS, Prayagraj (U.P.) which is located at 25˚ 24' 42" N latitude, 81˚ 50' 56" E longitude and 98 m altitude above the mean sea level. The area is situated on the right sight of the river Yamuna at Prayagraj Rewa road national highway at a distance of about 5 km away from Prayagraj. The climate of Prayagraj city is sub-tropical. The summer season is very hot temperature reaching as high 48 ˚C and in winter season temperature reaching up to 2.5 - 4.5 ˚C. The experiment was layout by adopting factorial Randomized Block Design 3X3 with nine treatments with three replication and each treatments replicated three times. The factors were located randomly and 3 sowing dates and 3 Safflower varieties.

Results and Discussion

Plant Height: at 120 days, maximum plant height (83.13cm) and treatment combination T_9 (V_3D_3) and minimum plant height (70.93cm) and treatment combination T_1 (V_1D_1).

Flowering (%) late different date of sowing and varieties observed non-significant difference on flowering % been due to the late sowing but the maximum flowering % (37.63) was observed in treatment combination T_1 (V_1D_1) where as maximum flowering % (36.04) was observed in treatment combination T_5 (V_2D_2).

Number of Pod: late sowing but the maximum number of pod T_5 (43.20) was observed in treatment combination (V_2D_2), where as minimum number of pod T_1 (30.93) was observed in treatment combination (V_1D_1).

Test Weight: late sowing but, the maximum (1000) seeds test weight (53.13) was observed in treatment combination T_5 (V_2D_2), where as minimum (1000) seeds test weight (40.93) was observed in treatment combination T_1 (V_1D_1).

Grain Yield: at maximum grain yield (27.61) was observed in treatment combination T_9 (V_3D_3), where as minimum grain yield (26.04) was observed in treatment combination T_5 (V_2D_2).

Helio-thermal unit (HTU): required by the crop to attain its various phonological stages were calculated and the results. It may be seen that the safflower required (10770.2) HTU on an average complete its life. The crop sown on first date (18 December) required maximum (10770.2) heat units for its maturity. This was mainly due to highest accumulation of HTU during all phase of the crop (N. Rani *et al.* 2014).

Growing degree days GDD: accumulation was significantly highest in D_3V_3 (1440.3 degree days) than other sowing dates. The minimum GDD was accumulated in D_2V_2 sowing (1072.1 degree days). The GDD accumulation was highest in D_1 due to longer duration of crop growing period and lowest in D_3 sowing due to forced maturity caused by increase in temperature. The decrease in GDD may be due to decrease in the maturity period of the pearl millet. Similar result found by Murty *et al.* (2008) [12].

Photo thermal units (PTU): determined various phenophases under different date of sowing are presented. The result revealed that on an average Safflower required (12.92) PTU to attain its physiological maturity. This was varied between (10.25) to (12.92) PTU under different date of sowing. The maximum accumulated PTU up to maturity was observed in third date of sown crop.

Table 1: Effect of Different Micro-Environment Condition on Cultivation of Safflower (*Carthamus tinctorius* L.).

D/V	Germination (%)	Plant Height (cm)	Flowering	Pod per plant	Test weight (gm)	Grain yield (q/ha)
V_1	72.71	72.71	36.80	37.28	47.44	26.42
D_1	75.17	75.17	36.89	34.37	44.37	26.52
V_2	73.57	73.57	36.30	39.978	49.91	26.30
D_2	74.17	74.17	36.12	41.33	51.40	26.12
V_3	76.22	76.22	36.42	40.75	50.88	26.80
D_3	73.15	73.15	36.52	42.31	52.46	26.88
CD at 5% (VD)	0.96	0.96	0.30	1.22	1.237	0.30
SED(±) (Variety)	0.45	0.45	0.14	0.57	0.578	0.143

Table 2: Growing degree days (GDD) at different phonological stages of different Safflower cultivars as affected by planting time V_1 (NARI-NH-1(First Non-Spiny Hybrid in the World)

GDD									
V_1 (NARI-NH-1)				V_2 (NARI-6)			V_3 (NARI-H-15)		
Date of Sowing	**18 Dec**	**28 Dec**	**06 Jan**	**18 Dec**	**28 Dec**	**06 Jan**	**18Dec**	**28 Dec**	**06 Jan**
P_1	20	40	65.2	22	48	67.2	15	38	67.2
P_2	150.3	155.2	278.6	156.3	168.2	280.6	146.3	168.2	280.6
P_3	295.3	210.6	475.3	305.3	232.6	485.3	285.3	232.6	485.3
P_4	366.4	335.8	634.5	370.4	345.8	640.5	364.4	325.8	640.5
P_5	840	688.5	920.4	800	680.5	940.4	815	660.5	940.4
P_6	1215	1172.1	1434.3	1245	1072.1	1440.3	1225	1052.1	1440.3

Table 3: HTU at different phonological stages of different Safflower cultivars as affected by planting time V_1 (NARI-NH-1(First Non-Spiny hybrid in the world)

HTU									
V_1 (NARI-NH-1)				V_2 (NARI-6)			V_3 (NARI-H-15)		
Date of Sowing	**18 Dec**	**28 Dec**	**06 Jan**	**18 Dec**	**28 Dec**	**06 Jan**	**18Dec**	**28 Dec**	**06 Jan**
P_1	111.3	281.8	508.2	111.27	281.8	518.2	45.17	233.7	473.44
P_2	1056.3	1167.5	1634.7	1117.3	1157.5	1716.8	1056.37	1160.25	1488.04
P_3	2709.24	1431	2932.5	1600.03	1430	3359.5	1738.13	1362.44	2575.18
P_4	3762.1	1955.4	4209.7	2456.03	1824.4	4479.32	2825.05	2515.05	3690.04
P_5	6538.2	4328.7	6790.7	8083.43	4328.7	6945.16	5269.73	5578.73	6790.76
P_6	10407.3	8239.1	10770.2	11131.49	11026.7	10771.2	8885.29	9351.67	10773.3

Table 4: PTU at different phonological stages of different Safflower cultivars as affected by planting time V_1 (Nari-NH-1 (First Non-Spiny Hybrid in the World)

PTU									
V_1 (NARI-NH-1)				V_2 (NARI-6)			V_3 (NARI-H-15)		
Date of Sowing	**18 Dec**	**28 Dec**	**06 Jan**	**18 Dec**	**28 Dec**	**06 Jan**	**18Dec**	**28 Dec**	**06 Jan**
P_1	2.8	3.8	6.72	2.5	8.4	5.72	2.1	7.4	7.72
P_2	4.63	5.82	6.51	4.63	5.32	6.60	3.34	5.37	6.65
P_3	8.53	4.82	8.53	5.53	4.92	8.37	5.73	4.72	7.67
P_4	6.44	5.82	8.96	7.44	4.82	9.26	7.04	7.32	8.86
P_5	8.15	6.05	9.40	8.62	7.05	10.40	8.81	9.58	6.40
P_6	12.25	10.52	12.40	10.25	10.28	12.44	11.15	11.78	12.92

Conclusion

From the above study it is concluded that the safflower variety is found to be most suitable for sowing at 18 Dec Followed by variety Sown in 18 Dec. Meteorology parameter i.e. thermal, photo thermal and hydrothermal effected the growth and yield of Safflower varieties NARI-NH-1(First Non-Spiny Hybrid in the World), NARI-6 (Non-Spiny Variety) and NARI-H-15 (Spiny Hybrid) and sowing date 18 Dec provides favorable weather condition for better growth and yield under Prayagraj condition.

In case of late sowing condition the weather parameter were not favorable for the varieties NARI-NH-1(First Non-Spiny Hybrid in the World), NARI-6 (Non-Spiny Variety) and NARI-H-15 (Spiny Hybrid), thus effecting the of plant height, flowering and cluster which ultimately reduced the yield. The cost benefit ratio of treatment combination T_6 (T_6 x D_2) was maximum (1:1.49) where as minimum (1:1.13) was recorded in T_5 (T_5 x D_2). Therefore the treatment combination T_6 (T_6 x D_2) is recommended to the farmers of Prayagraj region for hybrid Safflower cultivation.

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