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Effect of nitrogen and potassium fertigation schedules on physiological parameters and soil available nutrient status

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Abstract
A field experiment was conducted at Water Technology Centre, College farm, Rajendranagar, Hyderabad during *rabi* 2017-18. The experiment was conducted in randomized block design with three replications and nine treatments; Basal dose of 90 kg P_2O_5 ha^{-1} through single super phosphate was applied to all the treatments by manual application. N fertilizer for (T_2 and T_9) were applied to soil in three equal splits at basal, 30 and 50 DAS and K fertilizer was applied to soil as basal at the time of sowing. Fertigation was imposed at 16 DAS to 88 DAS and completed in 19 and 10 splits in 4 and 8 days interval respectively. Drip irrigation was scheduled (T_1 to T_8, except T_9) once in 2 days based on daily data of USWB class ‘A’ pan evaporimeter and furrow irrigation (T_9) was at 1.0 IW/CPE ratio with 50 mm irrigation depth in furrows in between paired rows (80 cm/40 cm). The amount of total irrigation water applied was 3188 m^3 and 4666 m^3 in drip irrigation and furrow irrigation treatments, respectively. N and K with 4 days interval (T_7) have recorded higher plant growth parameters and the lowest was recorded in control (T_1). The available N and P content at final harvest was found to be not significantly influenced by different treatments but K content was significantly influenced by different treatments.

Keywords: Nitrogen, potassium fertigation schedules, physiogical parameters

Introduction
The projected population of India was expected to be around 1.48 billion by 2030. Water is becoming a limiting resource due to the multi-various demand from sectors. It is estimated that by 2050; total water withdrawal will be 1180 BCM. Out of which irrigation will be accounted for nearly 68% followed by domestic use 9.5%, industries 7%, power development 6% (CWC, 2014) [1]. In adopting MI technology ensures increased crop yield, high water use efficiency, reduced water and energy consumption and minimal weed problems. Water productivity of drip irrigation is three times higher than the furrow irrigation (Kadasiddappa, 2015) [5]. Chemigation technology has been introduced to improve the application of agro-chemicals via irrigation systems. Chemigation has ensured to improve stability of crops productivity, its use is being discontinued due to its potentially hazardous to the environment and its role in the physical resources degradation even and even so if applied improperly. Therefore, uniform application of such chemicals is necessary to insure considerable increase in production and real decrease in production costs. Drip fertigation with N and K is more common when compared to P fertigation. Fertigation with P has not been widely used, mainly because emitters can get clogged by the formation of insoluble P precipitates. Further, the cost of fertilizers could be reduced to partial supply of fertilizer through fertigation or only supplying N and K through drip system. and the required oil seeds production will be around 102.3 million tonnes by 2030 (DRMR, Vision 2030) [4]. With the burgeoning population, improved living standard and purchasing power of the people, the demand for vegetable oil in the country is increasing at the rate of about 4-6 per cent. Therefore there is an urgent need to improve the productivity of oilseed crops to bridge up the current demand-supply gap. Till now there is no major breakthrough to increase the production of vegetable oil through traditional crops. Sunflower is an important oilseed crop contributes 14 per cent of the total oilseed production from nine major oil seed crops. In India it was cultivated over an area of about 0.29 m ha with a production of 0.21m tonnes and productivity of 738 kg ha^{-1} (DoES, 2018) [3]. Karnataka occupies first position in India with respect to area (0.19 m ha) and production (0.10 m tonnes) followed by Bihar and Maharashtra. In Telangana, sunflower is being grown in an area of 11547 ha, producing 13,330 tonnes with an average yield of 1154 kg ha^{-1} (DoES, 2017) [2]. Application of fertilizers along with irrigation water through drip fertigation can improve sunflower yield and fertilizer use efficiency and meets crop demand throughout the crop growing season.

Materials

The experiment was conducted during *rabi* 2017-18 with DRSH-1 at Water Technology Centre, college farm, college of Agriculture, Rajendranagar, Hyderabad. The mean weekly maximum and minimum temperature ranged from 28 to 34.57 ^{0}C and 8.63 to 16.57 ^{0}C, respectively. The mean weekly maximum relative humidity (RH I) ranged from 67.86 to 92.29 per cent and minimum (RH II) ranged from 17.71 to 47.71 per cent. The mean weekly wind velocity ranged between 1.97 and 4.3 km h^{-1}. The mean weekly sunshine hours per day ranged from 6.87 to 9.7 h d^{-1}. The mean weekly pan evaporation (PE) ranged from 2.89 and 6.16 mm. No rainfall received during entire crop growth period. The experimental soil was sandy clay loam in texture, slightly alkaline in reaction and non-saline. The fertility status of the experimental soil was high in organic carbon, low in available N, medium in phosphorus and medium in available potassium contents. The experiment was laid out in randomized block design with three replications and nine treatments at 100% RDF viz., no application of N and K_2O fertilizers + drip irrigation (T_1), manual application of N and K fertilizers + drip irrigation (T_2), application of only N (75 kg ha^{-1}) through fertigation at 4 days interval (T_3), application of only N (75kg ha^{-1}) through fertigation at 8 days interval (T_4), application of only K (30 kg ha^{-1}) through fertigation at 4 days interval (T_5), application of only K (30 kg ha^{-1}) through fertigation at 8 days interval (T_6), application of N and K (75 kg N - 30 kg K_2O ha^{-1}) through fertigation at 4 days interval (T_7), application of N and K (75 kg N - 30 kg K_2O ha^{-1}) through fertigation at 8 days interval (T_8) and manual application of N and K fertilizers + furrow irrigation (T_9)**.** The irrigation to T_1 to T_8 treatments was scheduled at 0.8 Epan and T_9 at IW/ CPE of 1.0. Irrigations were scheduled based on the USWB Class A pan evaporation rates (0.8 replenishment factor) for treatments under drip irrigation (466.6 mm) and the calculated irrigation water was delivered in surface irrigation (318.8 mm). The recommended dose of fertilizer (RDF) 75, 90 and 30 kg N, P_2O_5 and K_2O ha^{-1}, respectively was applied in the form of Urea, Single Super Phosphate (SSP), and Murate of Potash (MOP) / Sulphate of Potash (SOP). A common dose of phosphorus was applied to all the treatments including control (T_1). For manual application treatments (T_2 and T_9) N was applied in three equal splits at basal, 30 and 50 DAS through urea and potassium was applied through MOP in a single basal dose. Fertigation was given at 4 and 8 days intervals starting from 16 DAS to 88 DAS.

Results and Discussion

The leaf area per plant increased with the age of the crop, reached peak at 90 DAS and decreased towards maturity. At 30 DAS highest leaf area value (1050 cm^2 $plant^{-1}$) was observed in manual application of N and K with furrow irrigation treatment (T_9) and the lowest (750 cm^2 $plant^{-1}$) was observed in treatment T_1 (control). At 60, 90 DAS and at harvest the lowest leaf area values were noticed with T_1 (Control) and the highest was noticed in T_7 (Fertigation of N + K at 4 days interval) which was at par with T_8 (Fertigation of N + K at 8 days interval) and significantly higher over all other treatments (Table 1).

The crop growth rate (CGR) values were low in the initial stage of the crop growth (30 DAS), reached maximum values at 60 and 90 DAS and declined towards maturity. At 30 DAS maximum CGR (10.50 g m^{-2} day^{-1}**)** was observed in T_9 (Manual application of N and K + furrow irrigation) and in all the remaining stages of the crop growth (60, 90 DAS and at harvest) the CGR was maximum with the crop fertigation of N and K at 4 days interval (T_7). The lowest CGR was observed in (T_1) control (Table 2).

The values of absolute growth rate for dry matter (g $plant^{-1}$ day^{-1}) obtained at various growth intervals are presented in Table 3. The mean values of AGR for dry matter between 0-30, 31-60, 61-90 DAS and 91DAS – Harvest are 0.65, 1.81,0.74 and 0.82 g $plant^{-1}$ day^{-1} respectively. The AGR was very rapid during 0-30 vegetative stage and decreased with maturity. The maximum AGR values were observed with fertigation of N and K at 4 days interval (T_7) and the lowest was observed in control (T_1)

The net assimilation rate (NAR) values presented in Table 4 were higher during the vegetative growth (31-60 DAS) and declined toward maturity. The NAR at various stages of crop growth was influenced by fertigation schedules. Crop fertigated with both N and K at 4 days and 8 days interval resulted maximum NAR at all the crop growth stages and the lowest was noticed in control (T_1).

Data on LAR at various crop growth stages presented in Table 5. LAR values were lower during initial stages of crop growth (30 DAS), increased gradually, attained peak at (60-90 DAS) and declined towards maturity. At all the stages maximum LAR was observed in T_7 (fertigation of N and K at 4 days interval) which is close with (T_8) and the lowest was observed in control (T_1).

Leaf area duration (LAD) values presented in Table 6 were lower during initial stages of crop growth (0-30 DAS), increased gradually, attained peak at (61-90 DAS) and declined towards maturity as a consequence of leaf senescence. At 30 DAS maximum LAD was observed in (T_9) manual application of N and K + furrow irrigation treatment but in all the remaining stages maximum values were observed in T_7 (fertigation of N and K at 4 days interval) and the lowest was observed in control (T_1).

The biomass duration (BMD), increased with the age of the crop up to maturity. Crop fertigated with both N and K at 4 days interval (T_7) recorded relatively higher BMD values than the rest of the treatments, this was followed by treatment T_8 (fertigation of N and K at 8 days interval). At all the stages of crop growth, the lower BMD values were observed in control (T_1).

Soil nutrients status after harvest

The available N, P and K status of experimental soil at harvest are presented in Table 8.

Soil available nitrogen status (kg N ha^{-1})

The available soil nitrogen at final harvest presented in Table 8 was found to be not significantly influenced by different treatments. It ranged from 161.1 to 199.1 kg N ha^{-1}. The highest N content was observed in T_3 (N at 4 days interval) (199.1 kg N ha^{-1}) followed by T_7 (193.5 kg N ha^{-1}) and T_8 (191.4 kg N ha^{-1}) and the lowest was noticed inT_1 (control) (161.1 kg N ha^{-1}). When compared to the initial available N status of the experimental soil (188.5 kg N ha^{-1}), a depletion of available N was noticed in manual application treatments (T_1 and T_9) and K with 4 and 8 days interval treatments (T_5 and T_6) and build up of available N in remaining fertigation treatments was noticed. The highest build up was noticed in T_3 (N at 4 days interval) (5.6%), followed by T_7 (N + K at 4 days interval) (2.6%).

Soil available phosphorous status (kg P_2O_5 ha^{-1})

The available phosphorus at final harvest was also found to be not significantly influenced by different treatments. It ranged from 41.93 to 58.73 kg P_2O_5 ha^{-1}. The highest available P content (58.73 kg P_2O_5 ha^{-1}) was noticed in T_8 (N + K at 8 days interval) and the lowest (41.93 kg P_2O_5 ha^{1}) was noticed in T_9 (manual application of N and K fertilizers + furrow irrigation). When compared to the initial available P status of the experimental soil (44.79 kg P_2O_5 ha^{-1}), a builtup of available P (12.42 to 31.12%) in all treatments was noticed except in T_9 (-6.31%).

Soil available potassium status (kg K_2O ha^{-1})

The available soil potassium at final harvest was found to be significantly influenced by different treatments. It ranged from 252 to 375.9 kg K_2O ha^{-1}. The highest K content (375.9 kg K_2O ha^{-1}) was observed in T_6 (K at 8 days interval) which was on par with T_7 (N + K at 4 days interval) (337.5 kg K_2O ha^{-1}) and T_5 (K at 4 days interval) and the lowest was noticed in T_1 (control) (252 kg K_2O ha^{-1}). Comparing the N and K application ferigation treatment with manual application, available K_2O content in fertigation (T_7) was found to be 14.5% higher than manual application with drip irrigated (T_2) and 7.8% in manual application with furrow irrigation (T_9). Among the manual application treatments no significant difference was noticed between drip and furrow irrigation methods. The furrow irrigation treatment (T_9) recorded 6.2% higher K_2O content than drip irrigation treatment (T_2). When compared to the initial available K status of the experimental soil (317.18 kg K_2O ha^{-1}), a buildup of available K was noticed in T_5, T_6, T_7 and T_8. The highest build up was noticed in T_6 (K at 8 days interval).

Table 1: Leaf area (cm^2 plant^{-1}) of *rabi* sunflower as influenced by N and K fertigation schedules.

Treatments	Leaf area (cm^2 plant^{-1})			
	30 DAS	60 DAS	90 DAS	At harvest
T_1 - Control (N_0K_0)	750	2250	1800	600
T_2 - Manual application of N and K + drip	900	3900	2700	750
T_3 - Fertigation of N at 4 days interval	900	4950	3300	900
T_4 - Fertigation of N at 8 days interval	900	4800	3300	900
T_5 - Fertigation of K at 4 days interval	900	3300	2550	750
T_6 - Fertigation of K at 8 days interval	900	2550	2400	750
T_7 - Fertigation of N and K at 4 days interval	900	5550	3750	1200
T_8 - Fertigation of N and K at 8 days interval	900	5250	3300	1200
T_9 - Manual application of N and K + furrow	1050	3150	2250	750
SEm ±	41.5	179	180.7	71.2
CD (p=0.05)	125.6	542.6	546.6	215.5

Table 2: Crop growth rate (g m^{-2} day^{-1}) of *rabi* sunflower as influenced by N and K fertigation schedules.

Treatments	CGR (g m^{-2} day^{-1})			
	0-30 DAS	31-60 DAS	61-90 DAS	91DAS- Harvest
T_1 - Control (N_0K_0)	7.50	30.00	40.50	24.00
T_2 - Manual application of N and K + drip	9.00	48.00	66.00	34.50
T_3 - Fertigation of N at 4 days interval	9.00	58.50	82.50	42.00
T_4 - Fertigation of N at 8 days interval	9.00	57.00	81.00	42.00
T_5 - Fertigation of K at 4 days interval	9.00	42.00	58.50	33.00
T_6 - Fertigation of K at 8 days interval	9.00	34.50	49.50	31.50
T_7 - Fertigation of N and K at 4 days interval	9.00	64.50	93.00	49.50
T_8 - Fertigation of N and K at 8 days interval	9.00	61.50	85.50	45.00
T_9 - Manual application of N and K + furrow	10.50	42.00	54.00	30.00
General mean	9.0	48.6	67.8	36.8

Table 3: Absolute growth rate (AGR) for drymatter (g plant^{-1} day^{-1}) of *rabi* sunflower as influenced by N and K fertigation schedule

Treatments	AGR (g plant^{-1} day^{-1})			
	0-30 DAS	31-60 DAS	61-90 DAS	91- Harvest
T_1 - Control (N_0K_0)	0.62	0.41	0.29	0.12
T_2 - Manual application of N and K + drip	0.66	1.87	1.08	0.86
T_3 - Fertigation of N at 4 days interval	0.64	2.47	0.78	0.68
T_4 - Fertigation of N at 8 days interval	0.64	2.30	0.86	0.66
T_5 - Fertigation of K at 4 days interval	0.64	1.17	0.98	0.68
T_6 - Fertigation of K at 8 days interval	0.62	1.14	1.01	0.53
T_7 - Fertigation of N and K at 4 days interval	0.66	2.97	1.88	0.76
T_8 - Fertigation of N and K at 8 days interval	0.65	2.68	1.87	0.69
T_9 - Manual application of N and K + furrow	0.71	1.26	1.01	0.69
General mean	0.65	1.81	0.74	0.82

Table 4: NAR (g dm^{-2} day^{-1}) of *rabi* sunflower as influenced by N and K fertigation schedule**.**

Treatments	NAR (g dm^{-2} day^{-1})		
	31-60 DAS	61-90 DAS	91- Harvest
T_1 - Control (N_0K_0)	0.069	0.023	0.014
T_2 - Manual application of N and K + drip	0.091	0.065	0.033
T_3 - Fertigation of N at 4 days interval	0.103	0.063	0.024
T_4 - Fertigation of N at 8 days interval	0.098	0.069	0.023
T_5 - Fertigation of K at 4 days interval	0.083	0.046	0.039
T_6 - Fertigation of K at 8 days interval	0.072	0.041	0.035
T_7 - Fertigation of N and K at 4 days interval	0.116	0.086	0.049
T_8 - Fertigation of N and K at 8 days interval	0.108	0.079	0.035
T_9 - Manual application of N and K + furrow	0.071	0.043	0.024
General mean	0.090	0.052	0.036

Table 5: Leaf Area Ratio (LAR) cm^2 g^{-1}of *rabi* sunflower as influenced by N and K fertigation schedule

Treatments	LAR cm^2 /g			
	30 DAS	60 DAS	90 DAS	At harvest
T_1 - Control (N_0K_0)	40.54	53.29	24.93	4.33
T_2 - Manual application of N and K + drip	45.23	51.32	28.50	5.59
T_3 - Fertigation of N at 4 days interval	46.88	53.31	33.33	7.35
T_4 - Fertigation of N at 8 days interval	47.12	54.48	31.95	7.59
T_5 - Fertigation of K at 4 days interval	47.12	50.77	28.44	6.86
T_6 - Fertigation of K at 8 days interval	46.39	48.20	26.15	7.34
T_7 - Fertigation of N and K at 4 days interval	49.69	61.01	35.56	8.17
T_8 - Fertigation of N and K at 8 days interval	48.15	62.55	33.43	7.59
T_9 - Manual application of N and K + furrow	45.30	53.30	25.20	6.81
General mean	46.27	55.34	29.72	7.18

Table 6: Leaf Area Duration (days) of *rabi* sunflower as influenced by N and K fertigation schedule.

Treatments	LAD (days)			
	0-30 DAS	31-60 DAS	61-90 DAS	91- Harvest
T_1 - Control (N_0K_0)	4.11	4.71	4.24	4.11
T_2 - Manual application of N and K + drip	4.42	12.47	6.18	5.73
T_3 - Fertigation of N at 4 days interval	4.27	16.44	6.29	5.20
T_4 - Fertigation of N at 8 days interval	4.24	15.33	6.04	5.01
T_5 - Fertigation of K at 4 days interval	4.24	7.82	5.07	3.56
T_6 - Fertigation of K at 8 days interval	4.13	7.62	4.20	3.76
T_7 - Fertigation of N and K at 4 days interval	4.38	19.80	7.67	5.89
T_8 - Fertigation of N and K at 8 days interval	4.33	17.87	7.04	4.60
T_9 - Manual application of N and K + furrow	4.73	8.40	5.71	4.62
General mean	4.32	12.05	4.92	5.46

Table 7: Biomass duration (g days) of *rabi* sunflower as influenced by N and K fertigation schedule

Treatments	Biomass duration (g days		
	31-60 DAS	61-90 DAS	91- Harvest
T_1 - Control (N_0K_0)	738.00	1410.00	1451.00
T_2 - Manual application of N and K + drip	1438.50	2764.50	2424.00
T_3 - Fertigation of N at 4 days interval	1686.00	2883.00	2214.00
T_4 - Fertigation of N at 8 days interval	1608.00	2713.50	2113.00
T_5 - Fertigation of K at 4 days interval	1101.00	2011.50	1891.00
T_6 - Fertigation of K at 8 days interval	1072.50	1870.50	1740.00
T_7 - Fertigation of N and K at 4 days interval	1927.50	3606.00	2897.00
T_8 - Fertigation of N and K at 8 days interval	1791.00	3391.50	2731.00
T_9 - Manual application of N and K + furrow	1206.00	2226.00	1994.00
General mean	1396.50	2541.83	2161.67

Table 8: Soil nutrients status (N, P_2O_5 and K_2O kg ha^{-1}) after harvest of *rabi* sunflower as influenced by N and K fertigation schedules**.**

Treatments	Available N, P_2O_5 and K_2O status after harvest		
	Soil Nitrogen	Soil Phosphorus (P_2O_5)	Soil Potassium (K_2O)
T_1 - Control (N_0K_0)	161.1 (-14.54)	58.52 (30.65)	252.0 (20.54)
T_2 - Manual application of N and K + drip	187.4 (-0.58)	50.36 (12.43)	294.6 (-7.09)
T_3 - Fertigation of N at 4 days interval	199.1 (5.61)	58.57 (30.76)	276.3 (-12.87)
T_4 - Fertigation of N at 8 days interval	189.0 (0.26)	51.20 (14.31)	270.1 (-14.83)
T_5 - Fertigation of K at 4 days interval	177.2 (-5.96)	57.98 (29.44)	335.0 (5.62)
T_6 - Fertigation of K at 8 days interval	169.2 (-10.22)	57.93 (29.33)	375.9 (18.53)
T_7 - Fertigation of N and K at 4 days interval	193.5 (2.64)	52.43 (17.06)	337.5 (6.39)
T_8 - Fertigation of N and K at 8 days interval	191.4 (1.56)	58.73 (31.12)	326.8 (3.02)

T_9 - Manual application of N and K + furrow	184.5 (-2.12)	41.93 (-6.31)	313.0 (-1.30)
SEm ±	11.79	4.57	15.35
CD (p=0.05)	NS	NS	46.42
Initial status	188.5	44.79	317.18

Figures in paranthesis indicate the per cent of buildup / depletion over initial status
* 100% RDF = 75-90-30 N- P_2O_5-K_2O kg ha^{-1}
* A common dose of phosphorus was applied as basal to all the treatments

Conclusion

From the study, it was inferred that the sunflower crop grown with drip fertigation at 100% RD of N and K (75 kg N - 30 kg K2O ha^{-1}) at 4 days interval from 16 to 88 DAS through Urea and Potassium Sulphate respectively, during rabi realized better crop growth and maintained soil nutrient status.

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