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Physiological approaches to improve productivity of safflower (*Carthamus tinctorius* L.) through foliar nutrition

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Abstract
A field experiment was conducted at Agricultural Research Station (ARS) Bheemarayanagudi, UAS, Raichur, Karnataka during RABI 2018, to study the influence of foliar spray of nutrients and PGRs on growth and yield of safflower (*Carthamus tinctorius* L.) variety A-2. The experiment was laid out in RCBD and was replicated thrice. There were twenty treatments consisting of primary (NPK@(2%), secondary (Ca, Mg,S @0.5%), micronutrients (Fe Zn B and Mn @ 0.1%), salicylic acid (200 ppm) and cycocel (4000 ppm) alone or in combinations. Foliar spray treatments *viz.*, CCC and SA were imposed at 40 and 50 DAS, respectively. The foliar sprays of essential nutrients were imposed twice at 60 and 80 DAS. Foliar spray treatment T_{19} representing combination of primary, secondary and micronutrients and SA and CCC spray, recorded significantly higher seed yield of and oil yield over control. The significant increase in the seed yield with treatment T_{19} may be due to the improvement in the yield traits namely number of capsules per plant^{-1}, number of seeds capsule^{-1} and test weight which were largely influenced by the growth parameters like plant height, leaf area, branching, plant total dry matter accumulation and its partition into leaf, stem and capsule. Thus improvement in the yield was seems to be due to timely supply of essential nutrients and PGRs.

Keywords: SA, CCC, grain yield, rabi sorghum, foliar spray

Introduction
Off the 25 species of *Carthamus*, Safflower (*Carthamus tinctorius* L.) is only a cultivated type. of oilseed crop. Traditionally, It is a multipurpose crop, has been grown for centuries in India for getting high-quality edible oil rich in linoleic or oleic acid which reduce low-density lipoprotein (LDL; bad cholesterol) without affecting high-density lipoprotein (HDL; good cholesterol) in blood (Smith, 1996). Safflower oil is highly stable and may be widely used in frozen/chilled foods or infant liquid nutrition formulations as it is good source of all essential amino acids except tryptophan in addition to protein, calcium, iron and potassium *etc.* Safflower flowers are known to have many medicinal properties for curing several chronic diseases, hypertension, cardiovascular diseases, sores, rheumatism, arthritis, spondylosis and sterility. It is a non allergenic and suitable in injectable medications. It is also used in cosmetics, paint varnish, soap, orange dye in fabrics, (carthamin), alkyd resins, leather, glass and cement industry. Safflower oil meal is a good feed cake. All essential amino acids except tryptophan were present in safflower in addition to protein, calcium, iron and potassium *etc.*
Though it has tremendous potential to be grown under varied conditions and to be exploited for various purposes, but the cultivation around the world is confined to scanty rainfall area. Further productivity of the crop is (651 kg ha ^{1}) poor as compare to other major oil seed crops particularly sunflower groundnut and rapeseed etc. (Anon., 2017) [1]. Generally It is being cultivated as rainfed *Rabi* crop under residual moisture situation. Because of the terminal drought which coincides with yield formation phase of the crop, plants are may not be able to absorb required nutrients. Further, enhanced early ageing of leaves due to low or under supply of nutrients and imbalance in plant growth regulators level due to drought, certainly results in source limitation. As a matter of fact, the expected level of physiological processes will not be taking place mostly production and translocation of assimilates. The nutritional imbalance in plants can be addressed rapidly and effectively through foliar spray to realize productivity potential.
Plant growth regulators play a vital role in improving important growth and yield attributing characters by optimising sources and sink relationship. The growth retardant cycocel (CCC) check the excess vegetative growth and reduces plant stature with more branching and keeps leaves green for long period and consequently improves grain quality and yield. On other hand, salicylic acid (SA) plays an important role in tolerance of abiotic stress. Salicylic acid

significantly alleviated the growth inhibition induced by drought and manifested by less decreased fresh and dry mass, plant height, root length, chlorophyll and many physiological roles. Therefore, the present investigation was under taken to improve the seed and oil yield through foliar spray mineral nutrients, CCC and SA.

Materials and Method

A field experiment was conducted at Agricultural Research Station (ARS) B-gudi, University of Agricultural Sciences, Raichur, Karnataka to study effect of foliar spray of essential nutrients and plant growth regulators on morphological, yield and yield parameters of safflower (var. Annigere-2). The experiment was laid out in randomized complete block design with 3 replications during 2018. The experiment consisting of 20 different treatment *i.e.*,T_1 = (Primary nutrients ie NPK @ 2%, source is water soluble 19 all commercial grade.) T_2 = (Secondary nutrients, source is Mg S and Ca @ 0.5%-water soluble commercially available Cab plus) T_3 = Micronutrients @0.1%- water soluble mixture of Iron Zinc and Boron commercially available Librel TMX 2) T_4 = T_1+T_2+T_3, T_5= Salicylic acid, @200ppm (laboratory grade) T_6= Cycocel 4000 ppm (Lihosin commercial grade was used,)T_7=T_5+T_6, T_8=T_1+T_5, T_9=T_1+T_6, T_{10}=T_1+T_7, T_{11}=T_2+T_5, T_{12}=T_2+T_6, T_{13}=T_2+T_7, T_{14}=T_3+T_5, T_{15}=T_3+T_6, T_{16}=T_3+ T_7, T_{17}=T_4+T_5, T_{18}=T_4+T_6, T_{19}=T_4+T_7 and T_{20}=control (without spray).At physiological maturity of crop stage, five plants were randomly selected and tagged from each net plot for the purpose of recording various observations. Plant height was measured from the ground level up to the tip of plant and expressed in centimeters. The leaf area per plant was worked out by disc method on dry weight basis as per Vivekanandan *et al.* (1972) [9]. Total dry matter production and its partition into leaf, stem and achenes were recorded at harvest. Seed yield per hectare was computed from seed yield per plot. The Air dried capsules from each net plot were threshed, cleaned and the weight of seeds was recorded as seed yield per plot and expressed as yield per hectares protein content was worked out by multiplying Nitrogen content with 6.25 and oil content by using NMR. The oil yield was worked out by multiplying the per cent oil with seed yield

Results & Discussion

Significantly higher plant height was recorded in T_{19} (107cm) over T_{20} control (101) and T_6 CCC spray (97). The increase in plant height with T_{19} might be due to the fact that, in time availability of the essential nutrients to the plant at the critical peak growth stages and the growth regulators might have helped in maintenance of balanced proper ratio of growth regulators. These nutrients might have helped in keeping more photosynthetic apparatus as a consequence more assimilates were produced and increased the plant height. (Jasim Iqbal *et al.,* 2016) [5]. On the other hand, significantly least plant height by T_6 -CCC spray, might be due to the fact that CCC is a growth retardant which checks linear growth of the plants. (Dhillon and Sidhu (2001) [3]

Leaf area indicates the photosynthetic capacity of the crops. Among the treatments, T_{19} recorded higher leaf area (29.8 dm^2 $plant^{-1}$) over control (23.9 dm^2 $plant^{-1}$) Increased leaf area might be due to increased plant height, increased branches and more number of leaves per plant, in addition to improved photosynthetic capacity by the foliar fertilization of major nutrients *viz.*, nitrogen, phosphorus and potassium including the micronutrients (Prajwal *et al*. (2018) and Bharad *et al*. (1995) [2].

Treatment T_{19} recorded higher Total Dry matter accumulation (99.2 g $plant^{-1}$), while the control recorded the least dry matter (84.1 g $plant^{-1}$). The partion of dry matter into leaf and stem were also more with T_{19}. The improvement in the dry matter production and its partition may be due to greater absorption, assimilation, translocation and metabolization of nutrients resulting in increased physiological process viz photosynthesis and translocation, ultimately, higher dry matter production per plant. Ravi and Channal (2010) [7] in safflower

The treatment T_{19} showed the increased test weight (1.35 folds) compared to control. The in time supply of macro and micro nutrients in combination with CCC and SA, at critical stage of the crop, certainly stimulated cell division and expansion or elongation, consequently increasing number and weight of grains, resulting in enhanced accumulation of assimilate in the grains and thus heavier grains. Thus it indicates the improved sink aize and sink capacity which was largely influenced by higher dry matter production, leaf weight, higher photosynthesis and sugar accumulation (Shekoofa *et al*. (2008).

The foliar application of essential nutrients in combination with PGRs particularly treatment T_{19} recorded significantly (1643.7 kg ha^{-1}) higher seed yield compared to unspray control (1019.6 kg ha^{-1}). This increase in yield might be due to the additional availability of essential macro and micro nutrients which might have improved source and vegetative sink and was evident from higher leaf area, leaf weight perlant, stem weight, plant height and total dry matter. Further, it is was observed that, not only the source, but sink size and sink capacity were also improved and was clear from more number of seeds per capsule and more achene weight per capsule and test weight of the achenes. Laxmamma *et al*. (1996) [6] and Senapathi *et al*. (1999) [8] and Gebremedhin *et al*. (2015) [4]. Hence foliar spray of all essential nutrients in combination with SA and CCC seems to be beneficial in realising potential yield.

Table 1: Morphological parameters as influenced by foliar spray of PGRs& essential nutrients in safflower

Treatments	Total dry matter (g $plant^{-1}$)	Leaf dry weight (g $plant^{-1}$)	Stem dry weight (g $plant^{-1}$)	Plant height (cm)	Leaf area (dm^2)	No. of leaves per plant
T_1- Primary nutrients @ 2%	84.8	5.5	60.5	109	25.7	92.3
T_2- Secondary nutrients @ 0.5%	91.8	5.2	61.6	104	27.2	94.8
T_3- Micronutrients @ 0.1%	86.9	4.8	59.5	104	28.6	97.5
T_4- Primary @ 2% + Secondary @ 0.5% + Micronutrients @ 0.1%	90.7	5.8	62.5	105	26.0	95.4
T_5- SA @ 200 ppm	92.6	5.5	63.4	106	28.4	94.8
T_6- CCC @ 2500 ppm	88.4	6.1	60.0	097	28.1	96.3
T_7- SA @ 200 ppm + CCC @ 2500 ppm	91.2	5.4	62.5	107	25.9	98.3
T_8- Primary nutrients @ 2% + SA @ 200 ppm	92.6	6.2	62.4	101	27.2	97.8
T_9-Primary nutrients @ 2% + CCC@ 2500 ppm	84.8	5.8	60.0	106	28.2	98.9

T_{10}-Primary nutrients @ 2% + SA @ 200 ppm + CCC @ 2500 ppm	92.6	6.0	62.8	103	26.7	97.9
T_{11}- Secondary nutrients @ 0.5% + SA @ 200 ppm	88.1	5.5	59.7	105	28.4	95.3
T_{12}- Secondary nutrients @ 0.5% + CCC@ 2500 ppm	91.0	5.2	62.0	105	26.3	98.8
T_{13}-Secondary nutrients @ 0.5% + SA @ 200 ppm + CCC @ 2500 ppm	86.2	5.1	64.0	106	27.4	97.8
T_{14}- Micronutrients @ 0.1% + SA @ 200 ppm	90.5	5.4	62.8	105	26.9	96.3
T_{15}- Micronutrients @ 0.1% + CCC @ 2500 ppm	90.7	6.2	60.5	105	25.2	97.7
T_{16}- Micronutrients @ 0.1% + SA @ 200 ppm + CC @ 2500 ppm	93.2	5.8	63.7	106	27.4	98.0
T_{17}- Primary @ 2% + Secondary @ 0.5% + Micronutrients @ 0.1% + SA @200 ppm	95.2	6.9	64.9	112	28.9	99.6
T_{18}- Primary @ 2% + Secondary @ 0.5% + Micronutrients @ 0.1% + CCC @ 2500 ppm	97.4	7.1	67.1	107	29.1	100.8
T_{19}- Primary @ 2% + Secondary @ 0.5% + Micronutrients @ 0.1% + SA @ 200 ppm + CCC @ 2500 ppm	99.2	7.4	68.4	107	29.8	101.9
T_{20}- Control	84.1	4.2	58.4	101	23.9	88.3
Mean	91.4	5.8	62.3	105	27.2	96.9
SE.M (±)	1.1	0.1	2.0	1.0	0.4	1.7
CD at 5%	3.1	0.4	6.0	2.7	1.3	4.8

Table 2: Influence of foliar spray of essential nutrients and plant growth regulators on yield and yield attributes in safflower

Treatments	No of capsules plant[1]	No of seeds capsules[1]	Test weight (1000 seeds) g	Per cent Protein content	Oil yield (kg ha^{-1})	Seed yield (kg ha^{-1})
T_1- Primary nutrients @ 2%	18.2	19.66	53.48	17.8	345.7 (30.5)	1120.7
T_2- Secondary nutrients @ 0.5%	21.2	22.7	51.64	18.1	381.7 (30.9)	1224.8
T_3- Micronutrients @ 0.1%	22.0	19.89	52.24	19.4	416.9 (31.4)	1318.4
T_4- Primary @ 2% + Secondary @ 0.5% + Micronutrients @ 0.1%	22.2	21.35	54.25	16.4	429.7 (30.2)	1415.9
T_5- SA @ 200 ppm	19.2	23.04	22.24	19.6	430.0 (30.9)	1460.7
T_6- CCC @ 2500 ppm	19.2	19.68	49.53	19.2	459.9 (30.7)	1487.5
T_7- SA @ 200 ppm + CCC @ 2500 ppm	20.8	20.01	50.25	17.7	431.3 (31.0)	1502.5
T_8- Primary nutrients @ 2% + SA @ 200 ppm	19.2	21.68	51.84	18.7	484.4 (31.5)	1557.2
T_9-Primary nutrients @ 2% + CCC@ 2500 ppm	21.1	22.71	53.13	20.3	491.3 (31.0)	1589.0
T_{10}-Primary nutrients @ 2% + SA @ 200 ppm + CCC @ 2500 ppm	23.2	23.03	50.35	16.3	444.4 (31.4)	1490.5
T_{11}- Secondary nutrients @ 0.5% + SA @ 200 ppm	22.2	22.41	51.04	18.3	428.8 (31.3)	1459.7
T_{12}- Secondary nutrients @ 0.5% + CCC@ 2500 ppm	21.2	19.27	49.40	20.0	473.8 (31.0)	1517.4
T_{13}-Secondary nutrients @ 0.5% + SA @ 200 ppm + CCC @ 2500 ppm	19.2	21.37	54.75	18.5	494.6 (31.4)	1566.1
T_{14}- Micronutrients @ 0.1% + SA @ 200 ppm	22.2	20.70	53.15	19.0	485.1 (31.1)	1590.0
T_{15}- Micronutrients @ 0.1% + CCC @ 2500 ppm	21.86	23.73	52.82	18.2	472.8 (30.6)	1537.3
T_{16}- Micronutrients @ 0.1% + SA @ 200 ppm + CC @ 2500 ppm	19.6	22.04	51.59.	17.7	474.1 (31.1)	1580.1
T_{17}- Primary @ 2% + Secondary @ 0.5% + Micronutrients @ 0.1% + SA @200 ppm	22.9	23.75	55.22	21.4	508.8 (31.7)	1592.0
T_{18}- Primary @ 2% + Secondary @ 0.5% + Micronutrients @ 0.1% + CCC @ 2500 ppm	23.6	24.01	53.58	23.0	516.7 (31.8)	1612.9
T_{19}- Primary @ 2% + Secondary @ 0.5% + Micronutrients @ 0.1% + SA @ 200 ppm + CCC @ 2500 ppm	23.9	24.72	56.57	23.07	530.5 (32.1)	1643.7
T_{20}- Control	17.5	18.25	48.84	17.5	350.9 (29.9)	1019.6
Mean	21.0	19.80	52.40	19.0	442.6 (31.2)	1462.9
SE. M (±)	0.88	0.86	0.69	0.4	9.5 (0..6)	69.2
CD at 5%	2.53	2.47	1.99	1.3	28.7 (1.58)	2.7
( ) figure in parenthesis indicate oil content						

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