J. Soils and Crops 29 (2) 348-353, December 2019

ISSN 0971-2836 (Print)
ISSN 2582-2756 (Online)
NAAS Rating - 4.46
Scientific Journal Impact Factor - 7.375

MORPHO-PHYSIOLOGICAL TRAITS AND YIELD IN SAFFLOWER AS INFLUENCED BY FOLIAR APPLICATION OF HUMIC ACID AND NAA

Vishal S. Hivare[1],Rajesh D. Deotale[2], Ashish P. Dhongade[3], Satish E. Pise[4], Dnyaneshwar A. Raut[5]and A. Blesseena[6]

ABSTRACT

In order to investigate influence of foliar application of humic acid at 300, 400 and 500 ppm and NAA at 25 and 50 ppm and their combined effects on morpho-physiological traits and yield of safflower (*Carthamust inctorus* L.), a field experiment was conducted at farm of Botany section, College of Agriculture, Nagpur during the *rabi* season of 2018-2019. The experiment was arranged in randomized block design and replicated thrice consisting twelve treatments. The foliar sprays at 40 and 70 DAS showed significant changes in all the growth parameters i.e. plant height, number of branches, leaf area, dry matter, RGR, NAR, seed yield ha^{-1} and harvest index. Treatment T_{10} (300 ppm humic acid + 50 ppm NAA) gave significantly higher results in all parameters under study. Also, the highest per cent increase in yield over control was observed in same treatment i.e. 56.56 per cent.

(Key words: Safflower, humic acid, NAA, foliar application, morpho-physiological parameters, yield)

INTRODUCTION

Safflower (*Carthamust inctorius* L.), is a member of Compositae or Asteraceae family cultivated mainly for its seed, which is used as edible oil. Traditionally, the crop was grown for its flowers, used for colouring and flavouring foods and making dyes, especially before cheaper aniline dyes became available, and in medicines. This is an important plant that its oil has been considered as valuable oil having more than 90% unsaturated fatty acids, especially linoleic and oleic acids (Mundel *et al.,* 1995). Safflower contains about 36 per cent of oil, which accounted for 8 per cent of the value of total agriculture produce.

Humic acid is an organically charged bio-stimulant that significantly affects plant growth and development and increases crop yield. It has been extensively investigated that humic acid improves physical, chemical and biological properties of soils. The role of humic acid is well known in controlling soil-borne diseases and improving soil health and nutrient uptake by plants, mineral availability, fruit quality, etc. Humic acid based fertilizers increase crop yield, stimulate plant enzymes or hormones and improve soil fertility.

NAA (Naphthalene Acetic Acid) is the synthetic auxin with the identical properties to that naturally occurring auxin. It prevents formation of abscission layer and thereby flower drop. It was observed that the growth regulators are involved in the direct transport of assimilates from source to sink (Sharma *et al*., 1989).

MATERIALS AND METHODS

A field experiment consisting twelve treatments with three replications in RBD was conducted during*r abi* 2017-2018 at farm of Botany section, College of Agriculture, Nagpur. Treatments comprised of T_1- Control, T_2- Foliar application of NAA @ 25 ppm, T_3- NAA @ 50 ppm, T_4- humic acid @ 300 ppm, T_5- humic acid @ 400 ppm, T_6- humic acid @ 500 ppm, T_7- NAA @ 25 ppm + humic acid @ 300 ppm, T_8- NAA @ 25 ppm + humic acid @ 400 ppm, T_9- NAA @ 25 ppm + humic acid @ 500 ppm, T_{10}-NAA @ 50 ppm + humic acid @ 300 ppm, T_{11}- NAA @ 50 ppm + humic acid @ 300 ppm and T_{12} NAA @ 50 ppm + humic acid @ 300 ppm.The gross plot size was 1.80 m × 2.40 m and net 1.50 m × 2.00 m with spacing of 45 cm x 20 cm. Two foliar sprays of humic acid and NAA were given at 40 and 70 DAS. Five plants from each plot were selected randomly and data were collected at40, 60, 80 and 100 DAS on plant height, number of branches, leaf area plant^{-1}, total dry matter production of plant. RGR and NAR were calculated at 40-60, 60-80 and 80-100 DAS. Seed yield ha^{-1} was recorded after harvest. Harvest index and per cent increase were also calculated. Data were analysed by statistical method suggested by Panse and Sukhatme (1954).

1, 3, 4, 5 and 6. P.G. Students, Botany Section, College of Agriculture, Nagpur
2. Professor, Botany Section, College of Agriculture, Nagpur

RESULTS AND DISCUSSION

Plant height

At 60, 80 and 100 DAS significantly highest plant height was recorded in the treatments T_{10} (50 ppm NAA + 300 ppm humic acid), T_{11} (50 ppm NAA + 400 ppm humic acid), T_7 (25 ppm NAA + 300 ppm humic acid), T_8 (25 ppm NAA + 400 ppm humic acid), T_9 (25 ppm NAA + 500 ppm humic acid) and T_{12} (50 ppm NAA + 500 ppm humic acid) when compared with treatment T_1 (control). At 40 DAS data was found non-significant.

Plant height is a manifestation of genetical potential and also it is beneficial character to increase yield of crop. Due to exogenous application of growth regulators there is increase in plant height has been reported and this may be due to fact that application of growth regulators promote the coleoptiles or stem section in rapid and dramatic within 5 to 10 minute. Effect of NAA on cell division and elongation in the presence of endogenous application of gibberellic acid might have resulted in increased plant height.

The above results correlates with findings of Neware *et al.* (2017), who revealed that foliar sprays of 50 ppm NAA + 400 ppm HA through VCW significantly enhanced plant height in chickpea. Guddhe *et al.* (2019) showed that foliar spray of 400 ppm humic acid + 50 ppm NAA registered significantly maximum increment in plant height.

Number of branches plant^{-1}

Branches are the site of the leaves, flower and capitula formation. Hence, they are closely associated with the photosynthetic activity and yield of plant. So, number of branches is desirable attribute for higher biomass production and yield.

At 60 DAS significantly maximum number of branches was produced by plant in treatmentsT_{10} (50 ppm NAA + 300 ppm humic acid), T_{11} (50 ppm NAA + 400 ppm humic acid), T_7 (25 ppm NAA + 300 ppm humic acid) and T_8 (25 ppm NAA + 400 ppm humic acid) over T_1 (control).Whereas, at 80 and 100 DAS significantly more number of branches was registered in treatments T_{10} (50 ppm NAA + 300 ppm humic acid), T_{11} (50 ppm NAA + 400 ppm humic acid), T_7 (25 ppm NAA + 300 ppm humic acid), T_8 (25 ppm NAA + 400 ppm humic acid) and T_9 (25 ppm NAA + 500 ppm humic acid) over T_1 (control). At 40 DAS data was found non-significant.

It was clear from above data that foliar application of humic acid and NAA individually increased number of branches plant^{-1}. It is known that humic acid is source of micro and macronutrients. These nutrients are quickly absorbed by the plant when humic acid is applied as foliar spray. Macronutrients like N, P and K are associated with the different plant processes viz., cell enlargement, translocation of solutes, formation of carbohydrates etc. It is associated with the increase in height and number of branches in present study.

Above results are in line with that of results of Behera *et al.* (2015), who used NAA as foliar spray to know its effect on morphological attributes on sesame and observed that 20 ppm NAA was significantly superior over control in terms of number of branches.Guddhe *et al*. (2019) showed that combined application of humic acid and growth hormone i.e. 50 ppm NAA + 400 ppm humic acid followed by 50 ppm NAA + 300 ppm humic acid produced maximum number of branches.

Leaf area plant^{-1}

Leaf area depends upon the number and size of leaves. Leaves play an important role in the absorption of light radiations and using it in photosynthetic process. Leaf size is influenced by light, moisture and nutrients. Hence, yield is depends on leaf area of crop.

At 60 DAS significantly maximum leaf area plant^{-1} was noted in treatment T_{10} (50 ppm NAA + 300 ppm humic acid) when compared with treatment T_1 (control). Whereas, at 80 and 100 DAS treatments T_{10} (50 ppm NAA + 300 ppm humic acid), T_{11} (50 ppm NAA + 400 ppm humic acid), T_7 (25 ppm NAA + 300 ppm humic acid), T_8 (25 ppm NAA + 400 ppm humic acid) and T_9 (25 ppm NAA + 500 ppm humic acid) showed their significance regarding leaf area when compared with treatment T_1 (control). At 40 DAS data was found non-significant.

Due to the application of hormone the hydrolysis of starch, fructose and sucrose increased to form glucose and fructose molecule from which more energy produced, there will be increase of water potential, cell expansion and cell plasticity. It promotes leaf growth, so that leaf area is increased. Agrawal and Dikshit (2008) stated that application of IAA, NAA and GA_3 increased the number of leaves in pea.

Similar results were reported by Deotale *et al.* (2012), who found that the exogenous application of 6% cow urine and 50 pmm NAA alone and in combinations on soybean were found more effective in enhancing leaf area, when compared with control. Guddhe *et al*. (2019) reported that most pronounced effect on leaf area plant^{-1} was exhibited by treatment 400 ppm humic acid + 50 ppm NAA followed by 300 ppm humic acid + 50 ppm NAA.

Dry weight plant^{-1}

At 60 and 80 DAS the significantly more mean values of dry weight were noticed under treatments T_{10} (50 ppm NAA + 300 ppm humic acid) and T_{11} (50 ppm NAA + 400 ppm humic acid when compared with T_1 (Control). Whereas, at 100 DAS treatment T_{10} (50 ppm NAA + 300 ppm humic acid) was significantly effective in producing maximum dry matter. But at 40 DAS data was found non-significant.

Application of growth regulators significantly increased the total dry matter accumulation and it might be due to increasing cell division and other physiological activities, due to the increase of leaf area more photosynthates are produced, due to this the total dry matter of the plant was increased. The increase of dry matter might be due to the accumulation of building units that accompanied by greater saccharides and protein content which is linked with the photosynthetic operator, increasing protein content may be due to the increase in the formation of rough endoplasmic reticulum that provides appropriate medium for increasing the polyribosomes and RNA.

The same results were reported by Kapase (2014), who got significantly highest dry matter plant^{-1} by foliar spray of 50 ppm NAA + 400 ppm HA through VCW followed by 50 ppm NAA + 300 ppm HA through VCW in chickpea. Siddik *et al.* (2015) undertaken experiment to show the response of sesame to foliar application of NAA and concluded that shoot and root dry weight was significantly maximum when 50 ppm NAA applied as foliar spray.

Relative Growth Rate (RGR)

During 1st phase i.e. at 40-60 DAS significantly maximum RGR was noted in treatments T_{10} (50 ppm NAA + 300 ppm humic acid), T_{11} (50 ppm NAA + 400 ppm humic acid) and T_7 (25 ppm NAA + 300 ppm humic acid) when compared with T_1 (contol). Whereas, during 2nd and 3rd phase i.e. 60-80 DAS and 80-100 DAS significantly highest RGR exhibited in treatments T_{10} (50 ppm NAA + 300 ppm humic acid), T_{11} (50 ppm NAA + 400 ppm humic acid), T_7 (25 ppm NAA + 300 ppm humic acid), T_8 (25 ppm NAA + 400 ppm humic acid), T_9 (25 ppm NAA + 500 ppm humic acid) and T_{12} (50 ppm NAA + 500 ppm humic acid) over control.

Above results relates with findings of Neware *et al*. (2017), who opined that foliar application of 350 ppm humic acid through VCW + 50 ppm NAA sprayed at 35 and 55 DAS on linseed exhibited significantly highest RGR in linseed. Guddhe *et al*. (2019) observed that treatments 400 ppm humic acid + 50 ppm NAA and 300 ppm humic acid + 50 ppm NAA were significantly superior over control in RGR.

Net Assimilation Rate (NAR)

Net assimilation rate (NAR), synonymously called as unit leaf rate expresses the rate of dry weight increase at any instant on a leaf area basis with leaf representing an estimate of the size of the assimilatory surface area (Gregory, 1926). Increase in NAR during reproductive phases might be due to increase efficiency of leaves for photosynthesis as a response of photosynthetic apparatus to increase demands for assimilates by growing seed fraction and also due to photosynthetic contribution by pod and sink demand on photosynthetic rate of leaves.

NAR at all stages i.e. at 40-60, 60-80 and 80-100 DAS were significantly superior in treatments T_{10} (50 ppm NAA + 300 ppm humic acid) and T_{11} (50 ppm NAA + 400 ppm humic acid) when compared with T_1 (control).

Kapase (2014) checked the effect of humic acid through vermicompost wash and NAA on chickpea and reported that foliar spray of 50 ppm NAA + 400 ppm HA through VCW followed by 50 ppm NAA + 300 ppm HA through VCW significantly enhanced NAR in chickpea. Guddhe *et al*. (2019) recorded that NAR of sesamum significantly enhanced by treatment 400 ppm humic acid + 50 ppm NAA followed by 300 ppm humic acid + 50 ppm NAA.

Seed yield

Seed yield is the economic yield which is final result of physiological activities of plant. Economic yield is the part of biomass that is converted into economic product. (Nichiporovic, 1960).

Source–sink relation contributes to the seed / grain yield. It includes phloem loading at source (leaf) and unloading at sink (seed and fruit) by which the economic part will be getting the assimilates synthesized by photosynthesis. Partitioning of assimilate in the plant during reproductive development is important for flower, fruit and seeds. Thus, crop yield can be increased either by increasing the total dry matter production or by increasing the proportion of economic yield (harvest index) or both (Gardner *et al.,* 1988).

Data regarding seed yield ha^{-1} (q) was significantly maximum in treatments T_{10} (50 ppm NAA + 300 ppm humic acid), T_{11} (50 ppm NAA + 400 ppm humic acid), T_7 (25 ppm NAA + 300 ppm humic acid), T_8 (25 ppm NAA + 400 ppm humic acid), T_9 (25 ppm NAA + 500 ppm humic acid), T_{12} (50 ppm NAA + 500 ppm humic acid) and T_3 (50 ppm NAA)over control and rest of the treatments.

The growth hormone reduces flower drop, abscission of flower and ultimately increase the seed yield and biomass production in safflower. Hormone plays a key role in the long distance movement of metabolites in plant. Auxinhave effect on phloem transport. The metabolites and nutrients are moved from leaves and other parts of plant into fruits (Seth and Warein, 1967). Humic acid has been shown to stimulate plant growth and consequently yield by acting on mechanisms involved in cell respiration, photosynthesis, protein synthesis, water nutrient uptake and enzyme activities (Chen *et al*., 2004) which results into increase in various growth characters viz., plant height, number of branches plant^{-1}, leaf area, total dry matter production which are correlated with increase in number of capitula plant^{-1}, number of seeds capitulum^{-1}, 1000 seed weight. These might be the reasons responsible for increase in yield of safflower in present investigation.

Siddik *et al.* (2015) demonstrated experiment to examine effect of foliar application of NAA on sesame and concluded that the foliar spray of 50 ppm NAA gave maximum seed yield in sesame. Guddhe *et al*. (2019) claimed that 50 ppm NAA + 400 ppm HA through VCW significantly enhanced seed yield in sesamum.

Harvest index (HI)

Harvest index (HI) is the genetic character of the crop and varies with cultivar. The harvest index of the crop generally remain unchanged but some crucial management practices make some changes in HI.

Among all treatments under study significantly more harvest index was exhibited in treatment T_{10} (50 ppm

Table 1. Effect of humic acid and NAA on plant height plant^{-1}, number of branches plant^{-1}, leaf area plant^{-1} and dry weight plant^{-1} in safflower

Treatments	Plant height plant^{-1} (cm)				Number of branches plant^{-1}				Leaf area plant^{-1}(dm^2)				Dry weight plant^{-1} (g)			
	40 DAS	60 DAS	80 DAS	100 DAS	40 DAS	60 DAS	80 DAS	100 DAS	40 DAS	60 DAS	80 DAS	100 DAS	40 DAS	60 DAS	80 DAS	100 DAS
T_1 (control)	35.69	50.80	61.87	73.07	8.60	10.07	13.13	16.27	5.78	21.67	30.70	31.12	5.96	9.72	27.1	34.96
T_2 (25 ppm NAA)	33.02	59.93	68.57	84.20	9.93	11.53	14.53	17.87	7.99	23.99	33.09	34.14	5.69	10.99	33.47	44.94
T_3 (50 ppm NAA)	34.83	60.27	71.07	85.63	9.24	11.53	14.87	17.93	7.76	24.64	33.43	34.62	5.75	11.27	35.2	47.39
T_4 (300 ppm humic acid)	36.56	58.70	68.47	81.37	6.84	10.60	14.27	17.67	7.79	23.69	32.51	33.68	5.65	10.56	31.92	42.5
T_5 (400 ppm humic acid)	35.37	56.80	66.53	78.00	7.87	10.53	13.93	17.27	6.97	23.43	31.70	32.82	5.79	10.35	30.3	39.89
T_6 (500 ppm humic acid)	39.21	54.03	65.10	76.23	9.13	10.27	13.67	17.07	7.25	22.38	31.06	32.46	5.66	10.03	28.95	37.91
T_7 (25 ppm NAA + 300 ppm humic acid)	33.03	68.20	86.23	96.40	6.07	12.70	17.20	19.20	7.28	25.92	36.04	37.53	5.12	12.52	42.13	60.13
T_8 (25 ppm NAA + 400 ppm humic acid)	38.81	65.27	82.95	93.57	6.47	12.60	16.40	19.13	7.16	25.74	35.69	37.25	5.57	12.31	40.82	57.29
T_9 (25 ppm NAA + 500 ppm humic acid)	33.01	64.37	82.67	89.57	8.80	12.27	15.73	18.93	7.11	25.67	35.55	36.14	6.08	12.02	39.11	53.95
T_{10} (50 ppm NAA + 300 ppm humic acid)	38.63	70.00	93.90	99.24	8.00	14.80	18.33	20.33	7.34	28.13	37.21	38.66	5.51	14.95	52.4	75.42
T_{11} (50 ppm NAA +400 ppm humic acid)	34.15	68.42	87.00	97.67	9.40	13.00	17.93	19.87	7.64	26.46	37.08	38.34	5.48	14.41	49.13	70.45
T_{12} (50 ppm NAA + 500 ppm humic acid)	33.21	61.57	81.30	88.20	8.33	12.13	15.73	18.53	6.68	25.02	34.31	35.16	5.79	11.41	36.47	49.96
SE (m) ±	2.28	3.16	4.85	4.63	0.57	0.76	0.91	0.57	0.47	0.95	1.55	1.36	0.36	0.76	2.45	3.41
CD at 5 %	-	9.26	14.23	13.58	-	2.22	2.68	1.66	-	1.35	2.20	1.92	-	1.07	3.47	4.82

Table 2. Effect of humic acid and NAA on RGR, NAR, seed yield hectare^{-1}, per cent increase in yield and harvest index in safflower

Treatments	RGR (g g^{-1} day^{-1})			NAR (g dm^{2} day^{-1})			Seed yield ha^{-1} (q)	Per cent increase in yield	Harvest Index (%)
	40-60 DAS	60-80 DAS	80-100 DAS	40-60 DAS	60-80 DAS	80-100 DAS			
T_1 (control)	0.0245	0.0513	0.0127	0.0156	0.0335	0.0127	9.99	-	25.58
T_2 (25 ppm NAA)	0.0329	0.0557	0.0147	0.0182	0.0397	0.0171	13.24	32.53	31.38
T_3 (50 ppm NAA)	0.0336	0.0569	0.0149	0.0189	0.0415	0.0179	13.37	33.83	31.68
T_4 (300 ppm humic acid)	0.0313	0.0553	0.0143	0.0172	0.0383	0.0160	12.97	29.83	29.82
T_5 (400 ppm humic acid)	0.0290	0.0537	0.0137	0.0168	0.0365	0.0149	12.93	29.43	29.54
T_6 (500 ppm humic acid)	0.0286	0.0530	0.0135	0.0163	0.0357	0.0141	12.45	24.62	27.92
T_7 (25 ppm NAA + 300 ppm humic acid)	0.0447	0.0607	0.0178	0.0252	0.0482	0.0245	14.51	45.25	36.79
T_8 (25 ppm NAA + 400 ppm humiic acid)	0.0397	0.0599	0.0169	0.0232	0.0468	0.0226	14.33	43.44	35.74
T_9 (25 ppm NAA + 500 ppm humic acid)	0.0341	0.0590	0.0161	0.0205	0.0446	0.0207	14.15	41.64	33.07
T_{10} (50 ppm NAA + 300 ppm humic acid)	0.0499	0.0627	0.0182	0.0305	0.0577	0.0303	15.64	56.56	41.94
T_{11} (50 ppm NAA +400 ppm humic acid)	0.0483	0.0613	0.0180	0.0295	0.0552	0.0283	14.67	46.85	38.47
T_{12} (50 ppm NAA + 500 ppm humic acid)	0.0339	0.0581	0.0157	0.0202	0.0426	0.0194	13.87	38.84	31.94
SE (m) ±	0.0024	0.0019	0.0010	0.0014	0.0028	0.0013	0.79		0.48
CD at 5 %	0.0070	0.0056	0.0029	0.0041	0.0083	0.0039	2.31		1.42

NAA + 300 ppm humic acid) when compared with control and rest of the treatments. Also, treatments T_{11} (50 ppm NAA + 400 ppm humic acid), T_7 (25 ppm NAA + 300 ppm humic acid), T_8 (25 ppm NAA + 400 ppm humic acid), T_9 (25 ppm NAA + 500 ppm humic acid), T_{12} (50 ppm NAA + 500 ppm humic acid), T_3 (50 ppm NAA), T_2 (25 ppm NAA), T_4 (300 ppm humic acid), T_5 (400 ppm humic acid) and T_6 (500 ppm humic acid) significantly enhanced harvest index in a descending manner when compared with control and rest of the treatments.

Harvest index is the proportion of biological yield represented by economic yield. It is the coefficient of effectiveness or the migration coefficient. Harvest index reflects the proportion of assimilate distribution between the economic and total biomass (Donald and Hamblin,1976). Increase in harvest index might be the result of coordinated interplay of growth and development characters.

The significant effect of humic acid and NAA on harvest index was confirmed by Neware *et al.* (2017), who indicated that foliar application of 350 ppm humic acid + 50 ppm NAA and 300 ppm humic acid + 50 ppm NAA significantly increased harvest index in linseed when compared with control.

Above findings about harvest index are in accordance with that of obtained by Guddhe *et al.* (2019), who used various concentrations of humic acid and NAA on sesamum and showed that foliar spray of 400 ppm humic acid + 50 ppm NAA followed by 300 ppm humic acid + 50 ppm NAA significantly enhanced harvest index.

From the overall results it can be stated that foliar nutrition through humic source and NAA with different concentrations improved morpho-physiological, chemical and biochemical and yield and yield contributing characters significantly. The highest per cent increase in yield over control was observed in foliar application of 50 ppm NAA + 300 ppm humic acid i.e. 56.56 per cent. Next to this treatment foliar spray of 50 ppm NAA + 400 ppm humic acid also enhanced yield by 46.86 per cent over control.

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Rec. on 15.07.2019 & Acc. on 25.07.2019