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NUTRIENT UPTAKE AND NUTRIENT USE EFFICIENCY OF SUNFLOWER IN RESPONSE TO ZN AND B MICRONUTRIENT FERTILIZATION

R. Rex Immanuel*

Department of Agronomy, Faculty of Agriculture, Annamalai University, Annamalainagar – 608002, Tamil Nadu, India.

*E-mail: rrximmanuel@gmail.com.

Abstract

A field experiment was carried out at Annamalai University Experimental Farm, Annamalainagar, Tamil Nadu during summer season of 2014 (February to May) to study effects of recommended dose of NPK fertilizers along with soil and foliar fertilization of zinc and boron on seed yield, nutrient uptake and nutrient use efficiencies of irrigated sunflower. The experiment consist of 12 treatment combinations which includes recommend dose of fertilizer (RDF) as control and RDF along with combinations of Zn and B soil and foliar fertilization at different crop growth stages. The study revealed that 60 kg N, 90 kg P_2O_5 and 60 kg K_2O ha^{-1} along with soil application of micronutrients $ZnSO_4$ 25 kg ha^{-1}, borax 5 kg ha^{-1} and foliar fertilization of $ZnSO_4$ 0.5 per cent at star bud stage and borax 0.2 per cent at ray floret stage was the optimal agronomic micronutrient management treatment for obtaining maximum seed yield (2194 kg ha^{-1}), higher nutrient uptake (76.38 Kg N, 18.73 kg P and 81.51 kg K ha^{-1}), NUE (36.56), PUE (24.37), agronomic efficiency (19.7 kg N and 13.13 kg P_2O_5 ha^{-1}), apparent nutrient recovery (63.70, 11.92 and 50.08 % N, P_2O_5 and K_2O, respectively), internal efficiency (28.74, 117.13 and 26.91 N, P_2O_5 and K_2O, respectively) and physiological efficiency (30.92, 110.15 and 39.33 N, P_2O_5 and K_2O, respectively) of summer irrigated sunflower crop.

Key words: Boron, foliar fertilization, nutrient use efficiency, soil application, zinc

Introduction

Sunflower (*Helianthus annuus* L.) accounts the fourth place among the vegetable oilseeds subsequent to soybean, oil palm and canola in the world. Although sunflower is generally regarded as a temperate zone crop, it has been considered as a potential crop in the semi-arid regions. Sunflower offers an attractive price for the produce, and highly profitable compared to other crops in similar maturity groups. It holds a great potential as an oilseed crop for improving oilseed production due to its short duration, high per day productivity, photoinsensitivity, wider acclimatization, and polyunsaturated fatty acids rich edible oil. Today, world area under sunflower is 27.29 million ha with an annual production and productivity of 49.56 million tonnes and 1820 kg ha^{-1}, respectively (NSA, 2019). In India, it is cultivated over an area of about 0.39 million ha with a production of 0.34 million tonnes and productivity of 842 kg ha^{-1} (USDA, 2018). However, sunflower productivity in India is far below the genetic potential yield of crop (4250 kg ha^{-1}) and the average productivity of major sunflower producing countries in the world (2124 kg ha^{-1}) (Leite *et al*., 2014). The productivity of sunflower in terms of seed yield, oil and protein output varies widely depending on multifarious factors such as agro climatic condition of the locality, inappropriate choice of cultivar, land preparation, timely sowing, moisture deficit situation, nutrient imbalance, degraded status of growing medium especially soil, lack of improved agronomic crop management practices, varying planting pattern, *etc*.

Insufficient and/or imbalanced fertilization including micronutrients has been identified as one of the critical situation in oilseed productivity. Sustainable production of sunflower requires efficient use of inputs maintaining optimum yield and input use efficiency under resource constraint situations. Soils deficient in micronutrients are not capable of nourishing crop plant successfully and therefore low yield and quality of crops are obtained (Abbas, 2013). However, determination of an optimal level of nutrients is not an easy task since it depends on numerous factors, including the cultivar and the interactions among crop, environmental and agronomic factors. In coastal regions of northern Tamil Nadu, crop cultivation on soils where salinity problems already exist or may develop from the use of saline irrigation water during critical periods of growth leads to reduce nutrient use efficiency and cause yield reduction (Rex Immanuel and Ganapathy, 2019). Judicious use of macronutrients (N, P and K) along with micronutrients overcomes the ill effects caused by nutrient imbalance. Micronutrients are quantitatively the most required inorganic nutrient for plant growth that limits primary productivity of crops, unless supplied as fertilizer. Although many soils have large reserves of micronutrients, only a minute fraction is phytoavailable making many agricultural areas deficient with available micronutrients. Micronutrient deficiencies are becoming serious because of escalated nutrient demand from more intensive and exploitative agriculture coupled with use of single nutrient fertilizers and low amounts of organic manures (Dhanalakshmi and Narayana Rao, 2018). Deficiency of any micronutrients in soil adversely affects plant growth, development and ultimately yields, thus minimizes the usefulness of other agricultural inputs including N, P and K fertilizers. The efficiency of which can substantially be increased by application of micronutrients. The use of essential micronutrients in the right proportion and optimum quantity is the key to boost and sustain oil seed crop productivity.

Along with NPK fertilizers, micronutrients zinc (Zn) and boron (B) contributes an important role in nutrient uptake and nutrient use efficiency of sunflower. Zn is an essential plant nutrient element plays significant role in RNA and protein synthesis in plants. Zinc deficiency reduces net photosynthesis, inter nodal length of stem, increasing chlorosis and necrotic spots in the leaves and severely reduce yield (Alloway, 2008). Boron deficiency is the second most dominant problem, which is involved in the reduction of sunflower production (Tahir *et al*., 2014). Boron can influence photosynthesis and respiration and activate number of enzymatic systems of protein and nucleic acid metabolism in plants. It also decreases the rate of water absorption and transaction of sugars in plants. Combined application of Zn and B were found to effectively increase chlorophyll content, uptake of N, P and K from the soil (Gittle *et al.,* 2005). In fact, foliar fertilization does not totally replace soil applied fertilizer but it does increase the uptake and hence the efficiency of the nutrients applied to the soil ultimately productivity of crop (Kannan, 2010). Despite its considerable importance, little work has been done on sunflower with particular reference to its ability to grow well in summer season in the coastal regions of north Tamil Nadu. With the above background, the present investigation was planned to study the effect of individual and integrated applications of micronutrients Zn and B along with NPK fertilizers on sunflower seed yield, nutrient uptake and nutrient use efficiencies.

Materials and Methods

A field experiment was conducted at the Experimental Farm, Department of Agronomy, Annamalai University, Annamalai Nagar, Tamil Nadu during summer season (February – May) of 2014 to study the performance of micronutrients *viz*., Zn and B along with N, P and K fertilizers on the yield of hybrid sunflower (*Helianthus annuus* L.). The location is situated at 11°24' N latitude and 79°44' E longitude and at an altitude of +5.79 m above MSL (mean sea level). The weather at experimental site is moderately warm with hot summer months. During cropping season maximum temperature ranges from 29.2°C to 36.4°C with a mean of 32.8°C and the minimum temperature ranges from 20.8°C to 26.5°C with a mean of 23.6°C. The relative humidity fluctuates between 82 to 89 per cent. The entire cropping period received the rainfall of 5.6 mm distributed over 6 rainy days. The soil of the experimental field was clay loam with the soil reaction of 8.1 and the EC of 1.14 dSm^{-1}. The soil was low in organic carbon (0.42 %), low in available nitrogen (212 kg ha^{-1}), medium in available phosphorus (20 kg ha^{-1}), high in available potassium (279 kg ha^{-1}), low in available zinc (0.47 ppm) and low in available boron (0.21 ppm). Rice crop was grown during previous season with standard package of practices.

The sunflower hybrid 'Sun-bred' was used for the study. The treatments consisted of T_1 –RDF as Control (60 kg N, 90 kg P_2O_5 and 60 kg K_2O ha^{-1}), T_2 – RDF + $ZnSO_4$ 25 kg ha^{-1} (soil application - SA), T_3 – RDF + Borax 5 kg ha^{-1} (SA) T_4 - RDF + $ZnSO_4$ 0.5 % foliar application at star bud stage (FA - SBS), T_5 - RDF + Borax 0.2 % foliar application at ray floret stage (FA at RFS), T_6 - RDF + $ZnSO_4$ 25 kg ha^{-1} (SA) + Borax 5 kg ha^{-1} (SA), T_7 - RDF + $ZnSO_4$ 25 kg ha^{-1} (SA) + $ZnSO_4$ 0.5 % FA at SBS, T_8 - RDF + $ZnSO_4$ 25 kg ha^{-1} (SA) + Borax 0.2 % FA at RFS, T_9 - RDF + Borax 5 kg ha^{-1} (SA) + $ZnSO_4$ 0.5% FA at SBS, T_{10} - RDF + Borax 5 kg ha^{-1} (SA) + Borax 0.2 % FA at RFS, T_{11} - NPK + $ZnSO_4$ 0.5% (FA - SBS) + Borax 0.2 % (FA - RFS) and T_{12} - RDF + $ZnSO_4$ 25 kg ha^{-1} (SA) + Borax 5 kg ha^{-1} (SA) + $ZnSO_4$ 0.5 % FA at SBS + Borax 0.2 % FA at RFS. The experiments were laid out in randomized block design with three replications.

Recommended agronomic management practices were followed as per the guideline of Department of Agriculture, Government of Tamilnadu other than micronutrient management. A recommended fertilizer schedule for hybrid sunflower (60 kg N, 90 kg P_2O_5 and 60 kg K_2O ha^{-1}) was adopted. As per treatment schedule, both zinc and boron were supplied from their respective sources and specific doses mentioned in the treatments by calculating the quantity based on the size of the plots. In control plot instead of foliar fertilization of micronutrients, same quantity of spray fluid water was sprinkled over the foliage. Zinc sulphate ($ZnSO_4$) was used as the source of zinc (containing 36 per cent Zn), whereas borax (containing 11 per cent boron) was used as the source of boron. Need based plant protection measures were taken up based on the economic threshold level of pest and disease incidence. The artificial pollination work was carried out every day between 8 a.m. to 11 a.m. for a period of 10 days after initiation of flowering. The sunflower crop was harvested at full physical maturity stage. The capitula in the net plot was harvested, threshed and sun dried for three days and seed yield was recorded at 14 per cent moisture content and expressed in kg ha^{-1}.

Indices for Assessment of Nutrient Efficiencies

Nutrient use Efficiency (NUE) : In this approach, nutrient use efficiency is calculated in terms of seed yield kg^{-1} of nutrient applied. NUE = (Seed yield (kg ha^{-1}) / Amount of nutrient applied (kg ha^{-1}).

Agronomic efficiency (AE) : Agronomic efficiency is worked out in terms of seed yield obtained from fertilized plot and unfertilized plot to kg^{-1} of nutrients applied. AE = {(Seed yield in fertilized plot (kg ha^{-1}) – Seed yield in unfertilized plot (kg ha^{-1}) / Quantity of nutrient applied (kg ha^{-1})}

Apparent Nutrient Recovery (ANR) (%) : Apparent nutrient recovery is the quantity of nutrients absorbed per unit of nutrient applied. It was computed as per the formula suggested by Pillai and Vamadevan (1978). ANR = [Uptake of nutrients in fertilized plot (kg ha^{-1}) – Uptake of nutrients in unfertilized plot (kg ha^{-1}) / Quantity of nutrients applied for the treatment (kg ha^{-1})] x 100

Physiological Efficiency (PE) : The physiological efficiency is the seed yield obtained per unit of nutrients absorbed. It was computed as follows (Yoshida, 1981). PE = [Seed yield in fertilized plot (kg ha^{-1}) – Seed yield in unfertilized plot (kg ha^{-1}) / Nutrient uptake in fertilized plot (kg ha^{-1}) – Nutrient uptake in unfertilized plot (kg ha^{-1})]

Internal Efficiency (IE) : Internal efficiency indicates per unit seed yield per unit nutrient uptake. IE = Seed yield (kg ha^{-1}) / Total nutrient uptake (kg ha^{-1}).

The experimental data were statistically analysed as suggested by Gomez and Gomez (1976). For significant results the critical difference was worked out at 5 per cent level.

Results and Discussion

Seed Yield and Nutrient Uptake

Incorporation of 60 kg N, 90 kg P_2O_5 and 60 kg K_2O ha^{-1} along with $ZnSO_4$ 25 kg ha^{-1} and Borax 5 kg ha^{-1} soil application and foliar application of $ZnSO_4$ 0.5 per cent at star bud stage and Borax 0.2 per cent at ray floret stage (T_{12}) significantly registered the highest seed yield of 2194 kg ha^{-1}. This treatment also excelled all other treatments by recording the highest N (76.38 kg ha^{-1}), P_2O_5 (18.73 kg ha^{-1}) and K_2O (81.51 kg ha^{-1}) uptake. The highest seed yield was mainly due to dominant role played by Zn and B in improving the photosynthetic ability and assimilating capacity of crop by being a component in various enzymatic and other biochemical reactions. Better translocation of nutrients from source to sink enabling better yield parameters and finally the seed yield of sunflower. In sunflower, both the trichomes and cuticle appear to be important for foliar nutrient absorption (Li *et al*., 2019). It absorbed the micronutrients during critical stages of the crop and encouraged the metabolic activities. These results are in line with the findings of Oyinlola (2007); Ramulu *et al*. (2011); Takir *et al*. (2014) and Bhattacharyya *et al.* (2015).

Table 1 : Seed yield and nutrient uptake as influenced by Zn and B fertilization

Treatments	Seed yield (kg ha $^{-1}$)	Nutrient uptake (kg ha^{-1})		
		N	P	K
T_1	1012	38.16	8.00	51.46
T_2	1348	60.46	14.08	64.70
T_3	1296	58.95	13.68	63.25
T_4	1520	63.82	15.15	68.54
T_5	1468	62.24	14.75	66.75
T_6	2087	74.60	18.25	79.92
T_7	1859	71.08	17.26	76.16
T_8	1981	72.84	17.74	78.05
T_9	1805	69.55	16.88	74.40
T_{10}	1610	65.63	15.67	70.41
T_{11}	1700	67.50	16.19	72.33
T_{12}	2194	76.38	18.73	81.51
S. Ed	51	0.79	0.21	0.86
CD(p=0.05)	101	1.64	0.42	1.80

The uptake of major nutrients by sunflower is mainly due to greater availability of N, P_2O_5 and K_2O due to integrated application of these macro nutrients, Zn and B soil application and foliar nutrition during critical periods. It involved in cambial activity of root hairs, root proliferation and cell development on root resulted in increased plant height, number of leaves, leaf area and maximum dry matter production (DMP) and ultimately uptake of N, P_2O_5 and K_2O. The results are in agreement with the findings of Karthikeyan and Suhkla (2008) and Siddiqui *et al*. (2009).

Micronutrient Zn is needed in small, but critical concentrations and if the amount available is not adequate, plants will suffer from physiological stress. Boron is also involved in some aspects of flowering, pollen germination, cell division, nitrogen metabolism, carbohydrate metabolism, active salt absorption and hormone movement in sunflower crop. The availability and uptake of major nutrients increases with increase in Zn content, because these micronutrients involved in activation of more than 300 enzymes in plants and responsible for auxin biosynthesis and protein synthesis and also boron content improves the sugar translation, *etc*. Production of photosynthates and their translocation to sink mainly depends upon availability of mineral nutrients. Most of the pathways are dependent on enzyme and coenzymes, which are synthesized with the help of micronutrients such as Zn, B and other major nutrients *viz*., N, P and K and subsequent build up of sunflower.

Concerning the effect of B on the nutrient uptake, six elements followed the order K> N> S> P> B> Zn and these were significantly influenced by B application (Hossain *et al*. 2011). Boron and potassium have overlapping roles to play in plant physiology and hence, are synergistic. Therefore, Zn and B both were serve in acting as a buffer and are necessary in the maintenance of conducting tissues and to exert a regulatory effect on N, P_2O_5 and K_2O are reported by Ramulu *et al*. (2011); Zahoor *et al*. (2011).

Efficiencies

Application of Zn and B micronutrients had remarkable influence on efficiencies of sunflower. Among the treatments, treatment T_{12} ($ZnSO_4$ 25 kg ha^{-1} (SA) + Borax 5 kg ha^{-1} (SA) + $ZnSO_4$ 0.5 per cent FA at SBS + Borax 0.2 per cent FA at RFS) registered the higher nitrogen use efficiency of 36.56, phosphorus use efficiency of 24.37, agronomic efficiency of 19.7 kg N and 13.13 kg P_2O_5 ha^{-1}, apparent nutrient recovery of 63.70, 11.92 and 50.08 % N, P_2O_5 and K_2O, respectively, internal efficiency of 28.74, 117.13 and 26.91 N, P_2O_5 and K_2O, respectively and physiological efficiency of 30.92, 110.15 and 39.33 N, P_2O_5 and K_2O, respectively of summer irrigated sunflower crop.

Nutrient use efficiency in plants is a function of capacity of soils to supply adequate levels of nutrients, and the ability of plants to acquire nutrients, transport them in roots and shoots and remobilise them to other parts of the plant, involving various soil and plant mechanisms that contribute to genetic variability in efficiency of uptake and utilization of nutrients (Abbadi and Gerendas, 2015; Abbadi , 2017). It is a measure of how well plants use the available mineral nutrients. It can be referred as yield (biomass) per unit input (fertilizer, nutrient content). NUE is a complex trait: it depends on the ability to take up the nutrients from the soil, but also on transport, storage, mobilization and usage within the plant, and even on the rhizosphere environment. NUE is of particular interest as a major target for crop improvement. Improvement of NUE is an essential pre-requisite for expansion of crop production into marginal lands with low nutrient availability (Khan *et al*., 2009).

Under optimal Zn and B micronutrient conditions, growth, DMP, flowering and seed development is enhanced, and growth period is early resulting in earlier maturity especially in summer season, leading to higher seed setting, yield and optimal agronomic efficiency, apparent nutrient recovery per cent, internal efficiency and physiological efficiency of the treatment T_{12} (soil application of micronutrients $ZnSO_4$ at 25 kg ha^{-1}, borax at 5 kg ha^{-1} along with foliar fertilization of $ZnSO_4$ at the rate of 0.5 per cent at star bud stage and borax 0.2 per cent at ray floret stage). In view of the above results it is decided that hybrid sunflower is highly responsive crop to Zn and B micronutrient fertilization and have positive effects on the uptake and utilization of major nutrients at the whole plant level and it may improve efficiency parameters. The present results supported the observations of Hawkesford *et al*. (2014).

Table 2 : Effect of micronutrients Zn and B on nutrient efficiency of sunflower

Treatments	Nitrogen use efficiency	Phosphorus use efficiency	Agronomic efficiency (kg ha^{-1})		Apparent nutrient recovery (%)		
			N	P_2O_5	N	P_2O_5	K_2O
T_1	---	---	---	---	---	---	---
T_2	22.46	14.97	5.60	3.73	37.16	6.75	21.06
T_3	21.60	14.40	4.73	3.15	34.65	6.31	19.65
T_4	25.33	16.88	8.46	5.64	42.76	7.94	28.46
T_5	24.46	16.31	7.60	5.06	40.13	7.50	25.48
T_6	34.78	23.18	17.91	11.94	60.73	11.38	47.43
T_7	30.98	20.65	14.11	9.41	54.86	10.28	41.16
T_8	33.01	22.01	16.15	10.76	57.80	10.82	44.31
T_9	30.08	20.05	13.21	8.81	52.31	9.86	38.23
T_{10}	26.83	17.88	9.96	6.64	45.78	8.52	31.58
T_{11}	28.33	18.88	11.46	7.64	48.90	9.10	34.78
T_{12}	36.56	24.37	19.70	13.13	63.70	11.92	50.08

Table 3 : Effect of micronutrients Zn and B on internal and physiological efficiency of sunflower

Treatments	Internal efficiency			Physiological efficiency		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
T_1	---	---	---	---	---	---
T_2	22.29	95.73	20.83	15.06	55.26	25.37
T_3	21.98	94.73	20.49	13.66	50.00	24.08
T_4	23.81	100.33	22.17	19.79	71.04	29.94
T_5	23.58	99.52	21.99	18.93	67.55	29.82
T_6	27.97	114.35	26.11	29.94	104.87	37.77
T_7	26.15	107.70	24.40	25.72	91.46	34.69
T_8	27.19	111.66	25.38	27.94	99.48	36.44
T_9	25.95	106.93	24.26	25.26	89.30	34.56
T_{10}	24.53	102.74	22.86	21.76	77.96	31.55
T_{11}	25.18	105.00	23.50	23.44	84.00	32.96
T_{12}	28.74	117.13	26.91	30.92	110.15	39.33

Conclusion

From the present investigation it is concluded that 60 kg N, 90 kg P_2O_5 and 60 kg K_2O ha^{-1} along with soil application of micronutrients $ZnSO_4$ 25 kg ha^{-1}, borax 5 kg ha^{-1} and foliar fertilization of $ZnSO_4$ 0.5 per cent at star bud stage and borax 0.2 per cent at ray floret stage was the optimal agronomic micronutrient management treatment for obtaining maximum seed yield, higher nutrient uptake, maximum nutrient use efficiencies, agronomic efficiency, apparent nutrient recovery, internal efficiency and physiological efficiency of summer irrigated sunflower crop.

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