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Anil Kumar Saxena
Associate Professor,
Department of Soil Science,
School of Agricultural Sciences,
SGRR University, Dehradun,
Uttarakhand, India

Suneeta Singh
Associate Professor,
Department of Horticulture,
School of Agricultural Sciences,
SGRR University, Dehradun,
Uttarakhand, India

Jogendar Kumar
Assistant Professor,
Department of Agricultural
Chemistry, RMP PG College,
Gurukul Nar San, Hardwar,
Uttarakhand, India

Corresponding Author:
Jogendar Kumar
Assistant Professor,
Department of Agricultural
Chemistry, RMP PG College,
Gurukul Nar San, Hardwar,
Uttarakhand, India

Efficacy of zinc and silicon on growth and yield attributes of rice (*Oryza sativa* L.) in low-hills of Uttarakhand

Anil Kumar Saxena, Suneeta Singh and Jogendar Kumar

Abstract
A field experiment was conducted to know the efficacy of zinc and silicon on growth and yield of rice under low hills of Uttarakhand was carried out during *kharif* season 2020-21 at Experimental Research Block, School of Agricultural Sciences, SGRR University, Dehradun, Uttarakhand, India. The nine treatment combinations *viz.* T_1= Control, T_{2-}=RDF @120:80:40, T_3=RDF @120:80:40 + Two Zinc spray@ 0.5%, T_4= RDF @120:80:40 + Two Si spray @ 0.2%, T_5=RDF @120:80:40 + Two Si spray @ 0.3%, T_6= NPK @150:80:40, T_7= NPK @150:80:40 + Two Zinc spray @ 0.5%, T_8= NPK @150:80:40 + Two Si spray @ 0.2%, T_9= NPK @150:80:40 + Two Si spray @ 0.3% were tested under randomized block design with three replications. The results revealed that the application of zinc and silicon significantly influenced the growth and yield parameters of rice. Plant height, Leaf area index (LAI), dry weight, number of tillers, panicle length, number of grains per panicle and 1000-grain weight were recorded maximum with the application of 120:80:40 kg ha^{-1} NPK + @ 0.5% Zn spray at 30 and 45 DAT. Grain yield and harvest index also influenced significantly with the application of zinc and silicon and maximum grain yield was recorded with the application of 150:80:40 NPK + two Zn spray 0.5% (65.88 q ha^{-1}) followed by treatment 150:80:40 NPK + Two Si spray @ 0.3% (63.46 q ha^{-1}) and lowest in T_1 control (30.12 q ha^{-1}). Harvest index was recorded non-significant.

Keywords: Zinc, silicon, growth parameter, yield parameter, grain yield, harvest index

Introduction

Rice (*Oryza satvia* L.) is one of the most important field crops after wheat in the world providing staple food to the millions. It is an indispensable source of calories for almost half of the population with in Asia. More than 90% of the world rice is produced and consumed in Asia, which is a native for 60% of the earth's population. Rice is the first most important crop in India where it is grown in an area of 43.79million ha^{-1} with a total production of 112.91 million tones and an average productivity of 2578 kg ha^{-1} (Ahuja *et al.*, 1995) [1]. India is first in terms of area (44.5 million ha) and second in production (172.58 million tonnes) (Anonymous, 2020) [3]. Basmati rice is primarily grown in north-western India and Pakistan. These rice cultivars are preferred for their long and slender kernels, which expand to 3-4 times their original length and remain fluffy on cooking. Paddy soils are usually deficient in organic matter because of high temperature and moisture, which causes rapid decomposition of organic matter (Aleshin *et al.*, 1978) [2]. Aromatic rice constitutes a small but special group of rice, which is considered best for aroma, superfine grain and better cooking qualities (Ghani and Shah, 1990) [8]. There are many known groups of aromatic varieties such as Basmati rice from India and Pakistan and Jasmine rice from Thailand. These groups and varieties differ in the grain length, shape, weight, density and in their cooking and eating quality. Aromatic rice has occupied a prime position in society for aroma, milling, cooking and eating qualities and has been considered auspicious (Bhat and Rashid, 1995) [4].

In India, zinc is considered as the fourth important yield limiting nutrient after nitrogen, phosphorus and potassium respectively (Epstein, 1995) [6]. The critical limit of available zinc in the soil suitable for rice growth is 0.6 mg kg^{-1}. Soil application of zinc increased the grain yield and foliar application of zinc increase the grain zinc concentration (Ghasal *et al.*, 2016) [9]. When rice was grown in different types of soil, up to 90 percent difference was observed in the grain Zn concentration in the same rice varieties (Bruning *et al.*, 2009) [5]. Silicon is an important micronutrient for healthy and competitive growth of all cereals including rice in Asia (Bruning *et al.*, 2009) [5]. Rice is one of highly sensitive crops to Zn deficiency and Zn limits growth and yield of rice.

Zinc deficiency in rice has been widely reported in many rice-growing regions of the world. In India 47 percent and in MP 60.3percent of the soils found deficient in Zn (FAO, 2020) [7]. Paddy soil conditions are usually not favorable for the availability of zinc and hence zinc deficiency has been reported countrywide in rice soils (Graham *et al.*, 2019) [11]. Role of silicon in plant health and growth has been investigated in silicon accumulating crops and it seemed significantly effecting (Hodson *et al.*, 2015) [12]. Research evidences proved that adequate uptake of silicon (Si) can increase the tolerance of agronomic crops especially rice to both biotic and abiotic stress (Jawahar *et al.*, 2015) [13]. Effects of silicon on yield are related to the deposition of the element under the leaf epidermis which results a physical mechanism of defense, reduces lodging, increases photosynthesis capacity and decreases transpiration losses (Jinab *et al.*, 2010) [14]. Silicon (Si) is the second most abundant element in the earth's crust and considered as a beneficial element for crop growth, especially for crops under poaceae family. Rice is a typical silicon accumulating plant and it benefits from silicon nutrition. Its supply is essential for healthy growth and economic yield of the rice crop. Silicon interacts favorably with other applied nutrients and improves their agronomic performance and efficiency in terms of yield response. Also, it improves the tolerance of rice plants to abiotic and biotic stresses. Hence, silicon management is essential for increasing and sustaining rice productivity (Korndorfer *et al.*, 2014) [15]. Accumulation of Si in leaves and tissues in addition to conferring resistance against fungal diseases and insect pests, can improve erectness of leaves, increase yield and alleviate water stress, salinity stress and nutrient deficiency or toxicity stresses as well. Silicon is also considered as an environmentally-friendly element in relation to soils, fertilizers and plant nutrition (Ma and Takahashi, 2002) [16]. In modern agriculture, Si has already been recognized as a functional nutrient for a number of crops, particularly rice and sugarcane, and plays an important role in the growth and development of crops, especially gramineae crops (Metwally, 2011) [17]. The hulls of poor-quality and milky-white grains (kernels) are generally low in silicon content, which is directly proportional to the silicon concentration in the rice straw (Yogendra *et al.*, 2014; Mohammad *et al.*, 2005) [31, 18].

Materials and Methods

A field experiment was conducted during *kharif* season of 2020 at Experimental Research Farm, School of Agricultural Sciences, SGRR University, Dehradun, Uttarakhand (29°58' N, 77°34' E). The area has a subtropical climate, with severe cold winter, and hot and dry summer and rainy season. The soil samples were collected randomly to analyze the physico-chemical properties from different spots on the experimental site at the depth of 0-15 cm before conducting the experiment and a composite soil sample was prepared after proper drying, mixing and sieving. Soil at the experimental site was sandy clay loam, having 6.8 pH, EC 0.8 with bulk density 1.37 Mg/m^3, plant-available water capacity 2.48 cm/15 cm, porosity 50.6%, organic C 0.86% and available N 281 kg, P 12.2 kg and K 174 kg/ha. The micronutrients were available Sulphur 9.50 ppm, Zn 0.55 ppm, B 0.46 ppm, Fe 4.34 ppm, Mn 5.48 ppm and Cu 0.88 ppm. The experiment consisted of nine treatment combinations *viz.* T_1 = Control, T_{2-} = RDF @120:80:40, T_3 = RDF @120:80:40 + Two Zinc spray@0.5%, T_4 = RDF @120:80:40 + Two Si spray @ 0.2%, T_5 = RDF @120:80:40 + Two Si spray @ 0.3%, T_6= NPK @150:80:40, T_7= NPK @150:80:40 + Two Zinc spray @ 0.5%, T_8 = NPK @150:80:40 + Two Si spray @ 0.2%, T_9= NPK @150:80:40 + Two Si spray @ 0.3% which were tested in randomized block design and replicated three times. Foliar application of zinc and silicon were applied at 30 and 45 DAT as per the treatment. The graded levels of NPK were applied through Urea, Single super phosphate and Muriate of potash. Half dose of nitrogen and full doses of phosphorus and potassium were applied basally at the time of transplanting. Healthy plant of paddy cultivar Pusa1637 were transplanted at 20 cm × 15 cm and at a depth of 2-3 cm on 9th July, 2020. Observations on growth and yield attributes were recorded from five selected plants from the net plots. All the data obtained from the experiment were analyzed statistically using the F-test as per the standard statistical procedure (Gomez and Gomez, 1984) [10] and least significant difference (LSD) values (P0.05) were used to determine the significance of difference between treatment means.

Results and Discussion

Growth attributes

Plant height was significantly influenced with the application of zinc and silicon with recommended dose of NPK. Tallest plants were recorded with the application of NPK 120:80:40 kg ha^{-1} + @ 0.5% Zn spray at 30 and 45 DAT (Table 2) followed by NPK 150:80:40 + Two Zinc spray @ 0.5% and NPK 150:80:40. Shortest plant was observed in control treatment. LAI of rice was recorded maximum (8.05) with the application of treatment $T_7$150:80:40 NPK + two Zn spray 0.5% at 30 and 45 DAT. Minimum LAI was recorded in control treatment. Dry weight of rice was influenced significantly with the application of zinc and silicon. Maximum dry weight with was recorded with the application of T_7 150:80:40 NPK + two Zn spray @ 0.5% at 30 and 45 DAT (51.44 g) and minimum dry weight was recorded in control treatment. It may be due to the application of RDF with zinc or silicon, which increase the availability of nutrients and silicon also increase the water use efficiency of rice and it also increase the chlorophyll content and resulted the maximum production of photosynthates. The present findings were quite similar with those of Shivay, *et al.*, 2015 [24]; Metwally, 2011 [17]; Pooniya and Shivay, 2012 [20]. Number of tillers, number of grains panicle^{-1}, weight of grain panicle^{-1}, and grain sterility percentage was influenced significantly with the application of zinc and silicon with RDF. Maximum number of tillers plant^{-1} (11.11) was recorded with the application of $T_7$150:80:40 NPK + two Zn spray @ 0.5% at 30 and 45 DAT (Table 3) while minimum recorded in control plot. Increase in number of tillers by Zn application may be attributed to its role in various Zn induced enzymatic activity and auxin metabolism which control growth of plant. These results are confirmatory with the findings of Ghani and Shah, 1990 [8]. Highest number of grain panicle^{-1} (187.56) was recorded with the application of $T_9$150:80:40 NPK + two Si spray @ 0.3% at 30 and 45 DAT and recorded minimum in control treatment. The efficiency of Si application in increasing the assimilation of carbohydrates in panicles, which leads to increased number of filled grains also reported by Jawahar *et al.*, 2015 [13]. An increasing trend of 1000- seed weight was recorded maximum with the application of T_7 150:80:40 NPK + two Zn spray 0.5% at 30 and 45 DAT. Grain sterility (%) of rice was recorded the application maximum with of $T_3$120:80:40 NPK + two Zn spray @ 0.5% at 30 and 45 DAT(22.76%) and minimum (13.35%) in treatment T_3- RDF 120:80:40 + Two Zinc spray @0.5% at 30 and 45 DAT. Weight of grain panicle^{-1} was recorded maximum in T_9 150:80:40 NPK + two Si spray 0.3% @ at 30 and 45 DAT (5.49 g) followed by T_8- NPK 150:80:40 + Two Si spray @ 0.2% at 30 and 45 DAT. Similar observations were also reported earlier by Singh and Shivay, 2016 [27] and Salton *et al.*, 2005 [32].

Table 1: Treatment Details

Number of Treatment	Combinations	Concentration
T_1	Control	-
T_2	Recommended Dose Fertilizer (RDF)	120:80:40
T_3	RDF+ Two zinc spray	120:80:40 + 0.5%
T_4	RDF+ Two silicon spray	120:80:40 + 0.5%
T_5	RDF+ Two silicon spray	120:80:40 + 0.3%
T_6	NPK	150:80:40
T_7	NPK+ Two zinc spray	150:80:40 + 0.5%
T_8	NPK+ Two silicon spray	150:80:40 + 0.2%
T_9	NPK+ Two silicon spray	150:80:40 + 0.3%

Table 2: Plant height (cm), leaf area index and dry weight (g) of rice as influenced by application of Zinc and Silicon

Treatments	Plant height (cm) (60DAT)	Leaf Area Index (60DAT)	Dry weight (g) (60DAT)
T_1- Control	104.22	4.41	30.54
T_2- RDF @120:80:40	129.56	7.10	37.14
T_3- RDF @120:80:40 + Two Zinc spray @ 0.5%	133.22	6.74	51.40
T_4- RDF @120:80:40 + Two Si spray @ 0.2%	127.44	7.20	46.51
T_5- RDF @120:80:40 + Two Si spray @ 0.3%	128.71	7.53	46.37
T_6- NPK @150:80:40	129.11	8.29	39.30
T_7- NPK @150:80:40 + Two Zinc spray @ 0.5%	131.92	8.05	51.44
T_8- NPK @150:80:40 + Two Si spray @ 0.2%	132.22	8.98	42.33
T_9- NPK @150:80:40 + Two Si spray @ 0.3%	132.67	6.87	44.86
S.E(m ±)	2.18	0.24	2.13
CD at 5%	6.58	0.74	6.46

Table 3: Effect of application of Zinc and Silicon on the growth attributes of rice

Treatment	No. of tillers plant^{-1}	No. of effective tillers plant^{-1}	Number of grains panicle^{-1}	1000 seed weight (g)	Grain sterility (%)	Weight of grain panicle^{-1} (g)
T_1- Control	5.56	3.67	132.11	27.69	22.76	3.44
T_2- RDF @120:80:40	10.11	7.33	176.22	31.25	18.69	4.29
T_3- RDF @120:80:40 + Two Zinc spray @ 0.5%	10.78	8.33	183.00	30.87	13.35	4.21
T_4- RDF @120:80:40 + Two Si spray @ 0.2%	10.00	8.22	179.11	31.41	16.37	4.42
T_5- RDF @120:80:40 + Two Si spray @ 0.3%	10.11	7.99	180.11	30.70	16.03	4.72
T_6- NPK @150:80:40	9.22	7.89	181.33	30.71	17.95	4.69
T_7- NPK @150:80:40 + Two Zinc spray @ 0.5%	11.11	8.56	180.44	32.77	17.29	4.35
T_8- NPK @150:80:40 + Two Si spray @ 0.2%	8.99	7.99	180.67	31.22	18.12	4.83
T_9- NPK @150:80:40 + Two Si spray @ 0.3%	10.67	8.34	187.56	30.76	18.36	5.49
S.E(m ±)	0.47	0.33	6.05	0.53	1.51	0.21
CD at 5%	1.41	1.02	18.31	1.61	4.59	0.63

Table 4: Effect of application of Zinc and Silicon on the Yield attributes of rice

Treatments	Grain yield (q ha^{-1})	Stover yield (q ha^{1})	Biological yield (q ha^{-1})	Harvest Index (%)
T_1- Control	30.12	42.31	72.44	41.59
T_2- RDF @120:80:40	52.06	62.28	114.34	45.53
T_3- RDF @120:80:40 + Two Zinc spray @ 0.5%	59.14	63.87	126.67	46.83
T_4- RDF @120:80:40 + Two Si spray @ 0.2%	53.04	65.98	119.02	44.59
T_5- RDF @120:80:40 + Two Si spray @ 0.3%	54.72	68.22	122.96	44.50
T_6- NPK @150:80:40	62.42	72.67	135.09	46.28
T_7- NPK @150:80:40 + Two Zinc spray @ 0.5%	65.88	73.28	139.16	47.32
T_8- NPK @150:80:40 + Two Si spray @ 0.2%	62.86	78.23	141.09	44.53
T_9- NPK @150:80:40 + Two Si spray @ 0.3%	63.46	75.79	139.23	45.60
S.E(m ±)	1.76	2.570	3.98	1.00
CD at 5%	5.31	7.77	11.99	3.02

Yield attributes

Grain yield of rice was significantly influenced with the application of zinc and silicon with NPK (Table 4). The highest grain yield was recorded under treatment T_7 150:80:40 NPK + two Zn spray 0.5% (65.88 q ha^{-1}) followed by treatment T_9- NPK 150:80:40 + Two Si spray @ 0.3%

(63.46 qha^{-1}) and lowest in T_1 control (30.12 q ha^{-1}). Supply of Zn by foliar sprays might have made adequate availability of Zn which has facilitated the growth of the plant, due to its involvement in many metallic enzyme system, regulatory functions and auxin production (Salton *et al*., 2005) [32], increased synthesis and transport of carbohydrates to the sink (Wang *et al*., 2014 and Yadav *et al*., 2018) [29, 30]. Straw and biological yield was significantly influenced by the application of treatment T_8-150:80:40 two Si spray 0.2% (78.23 and 141.09 q ha^{-1}). Minimum straw and biological yield were recorded from T_1 control (42.31 and 72.44 q ha^{-1}, respectively). Harvest index was recorded non-significant. Similar results were also earlier reported by Ghasal *et al.*, 2016 [9] and Yadav *et al*., 2018 [30].

Conclusion

On the basis of present experimental findings, it can be concluded that application of 150:80:40 kg ha^{-1} with two Zn foliar sprays at 30 and 45 days after transplanting improved the yield attributes of rice under low hills of Uttarakhand.

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