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Agronomic zinc bio-fortification increases fodder yield parameters in maize-legume intercropping systems

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Abstract

Field experiments were conducted for two successive years (2020 and 2021) to evaluate the growth and yield parameters with zinc fortification in maize + legume intercropping systems. The treatments comprised of five cropping systems and three zinc levels. The results of two year field experiments indicated that maize + soybean intercropping recorded higher plant height (257.85 cm and 263.81 cm), leaf area index and leaf stem ratio of maize at harvesting as compared to other maize based systems. However sole maize recorded highest dry matter accumulation (116.11 and 122.67 q ha^{-1}) in 2020 and 2021, respectively, as compared to maize + legume systems. Among the legumes, sole soybean recorded higher plant height and dry matter accumulation as compared to sole cowpea and intercropped legumes. Application of zinc significantly improved growth parameters and dry matter accumulation in all the cropping systems.

Keywords: Maize, legume, intercropping, fodder, zinc bio-fortification, dry matter

1. Introduction

Livestock rearing is an important occupation of farmers in North Western Himalayan region as livestock plays a multifaceted role in rural economy and food security. The majority of fodder (62%) is extracted from forests (trees, shrubs, leaves and herbaceous ground flora) and remaining (38%) is derived from agro-forestry systems, low altitude grasslands, degraded lands, high altitude grasslands and crop residues (Ahmad *et al.*, 2016) [1]. Despite forest and grazing land resources, there is a net deficit of fodder in the region. The requirement of the state for green fodder is around 13.21 million tonnes (mt), while as the availability of the green fodder is about 5.11 mt thereby leaving a deficit of around 63%. In case of dry fodder, the requirement is 8.52 mt while as the availability is around 4.55 mt, thus having a short fall of about 37% (Anonymous, XXIII Regional Committee Meeting, 2014) [4].

Green forages are rich and cheapest source of carbohydrates, proteins, vitamins and minerals for dairy animals. Amongst the non-legume cultivated fodders, maize produces higher nutritional quality along with good quantity of biomass (Chaudhary *et al*., 2012) [9]. Maize is considered ideal forage and is most suitable for silage making also. Although maize provides high yield in terms of dry matter, it produces forage with low protein content. Fodder legumes such as cowpea, soybean, rice bean etc. are rich sources of protein but their fodder yield is lower than cereal fodder (Iqbal *et al*., 2015) [14]. Diversification of cropping system is necessary to get higher yield and returns; to maintain soil health; to preserve environment and to meet the need of daily food and fodder requirement of humans and animals, respectively (Padhi and Panigrahi, 2006; Marer *et al*., 2007) [26, 23]. Among different legumes as intercrops, cowpea (*Vigna unguiculata*), provides highly palatable, succulent and quality fodder (Bisht *et al*., 2001) [6] and soybean [(*Glycine max* (L.) Merrill)] complements most forages and fits very well with maize (Yang *et al*., 2015) [29].

Zinc is essential for the growth in animals, human beings, and plants as it is vital to the crop nutrition as it is required in various enzymatic reactions, metabolic processes, and oxidation reduction reactions. Direct linkages between available micronutrient in the soil and their contents in forage and fodders have been widely studied and clearly established and it is also common in case of Zn (Nube and Voortman, 2006) [25]. About 50% of Indian soils are deficient in Zn causing low level of Zn and yield losses in fodder crops and affecting the health of the livestock (Singh, 2011) [27]. Jalali *et al.* (1989) [15] have reported the Diethylene triamine pentaacetic acid (DTPA)-extractable Zn to vary from 0.35 to 0.65 mg kg^{-1} in high altitude soils of Kashmir. The benchmark soils of Kashmir are deficient (0.15 to 1.00 mg kg^{-1}) in DTPA-extractable zinc (Kakar *et al.*, 2018). Hence, in addition to increasing crop yield for human consumption, micronutrient fertilization or fortification of crops may also address crop nutritional quality and micronutrient dietary concerns in plant-animal-human system (Cakmak, 2009) [7].

2. Materials and Methods

Field experiment entitled "Yield and Quality Assessment of Fodder Maize - Legume Intercropping Systems with Zinc Fortification" was conducted at Research Farm of ICAR-IGFRI, Regional Research Station, K D Farm, Rangreth, Srinagar, during *kharif* seasons of 2020 and 2021. The soil of the experimental field was sandy loam in texture having normal pH (6.9), bulk density (1.23 Mg m^{-3}), electrical conductivity (0.28 dS m^{-1}), medium organic carbon (0.72%), available nitrogen (295.7 kg ha^{-1}), available phosphorus (24.2 kg ha^{-1}) and available potassium (364.5 kg ha^{-1}) and low available zinc (0.36 ppm). The first fodder maize variety SFM-1released by SKUAST-K, a cross between GM-6 (Gujarat) and C-8 (SKUAST-K), was evaluated along with cowpea and soybean, under the present study. The experiment was laid out in a Factorial Randomized Block Design with two factors and each treatment replicated thrice. Treatment Combinations included five cropping systems i,e Sole Maize, Sole Cowpea, Sole Soybean, Maize + Cowpea (2:1), Maize + Soybean (2:1) and three Zinc levels**,** Zn0= Control or no Zinc application, Zn1 = 20 kg $ZnSO_4$ ha^{-1} (basal soil application) and Zn2 = 20 kg $ZnSO_4$ ha^{-1} (basal soil application) + 0.5% $ZnSO_4$ spray twice (30-35 DAS and 50 DAS). For data recording five plants were taken and each parameter was then averaged. For dry matter accumulation, harvested plants were first dried in shade for 48 hours and then in a hot air oven at 65±5 ºC to constant weight. The weight was recorded in gram and then converted into q ha^{-1}.

3. Results and Discussion

3.1 Plant height

The analysis of data (table 1) indicated that plant height of maize varied with the maize based cropping systems, however the differences were statistically non-significant during both the years. The results revealed that maize + soybean intercropping recorded highest plant height of maize (257.85 cm and 263.81 cm) at harvesting during both the years. Between the two legumes (table 2), soybean recorded significantly higher plant height in sole (129.1 and 130.3 cm) and also in intercropped systems as compared to cowpea. The beneficial effect of legume intercropping on growth and yield of maize has been advocated by many workers. Ike *et al.*, 2013 [13] and Ginwal, *et al.*, 2019 [12] reported higher plant height of maize in intercropped treatments as compared to sole stands. Diebel *et al*., 2000 [11], also reported lower growth parameters of legumes in intercropping systems compared to sole legume systems.

Zinc fertilization significantly influenced plant height irrespective of the cropping systems. Significantly higher plant height in maize (263.27 cm and 266.07 cm) and legumes (129.1cm and 132.2 cm) was recorded with Zn2 (soil + foliar application) compared to Zn1 (soil application) and Zn0 (control). The increased plant height may be due to the favourable influence of micronutrient (Zn) on rapid cell division and cell elongation. Similar results were reported by Kumar *et al*., 2016a; Amutham *et al*., 2019 [3] and Chand *et al*., 2017 [8].

3.2 Leaf Area Index

Leaf area index of maize (table 1) did not vary significantly with the cropping system, however, maize + legume intercropping recorded slightly higher leaf area index of maize over sole maize (5.57 and 5.59). With respect to legumes (table 2), LAI varied significantly (3.52 to 3.81) among the different cropping systems. Soybean recorded significantly higher LAI compared to cowpea in both sole as well as intercropped treatments.

Among the zinc levels, Zn1 and Zn2 recorded significantly higher leaf area index in all the cropping systems over control (Zn0). LAI increased from 5.53 and 5.55 to 5.72 and 5.75 in maize and 3.64 and 3.64 to 3.72 and 3.76 from Zn0 to Zn2 in 2020 and 2021, respectively. The increased leaf area with zinc application may be attributed to the role of zinc in functioning of photosynthetic enzymes and increased photosynthetic area. The findings are in agreement with the findings of Mehdi *et al*., 2012 [24] and Ahmad *et al*., 2018 [2].

3.3 Leaf-stem ratio

Leaf stem ratio is an important factor which is helpful to determine the palatability of any fodder as fodder with higher leaf stem ratio is generally preferred by the animals due to more palatability and digestibility. Cropping systems had no significant influence on leaf-stem ratio of maize (table 1). However maize + legume intercropping slightly increased leaf stem ratio of maize. The data further revealed that among legumes (table 2), cowpea based cropping systems (0.45 to 0.46) recorded higher leaf-stem ratio compared to soybean (0.41 to 0.42) at harvesting. Slightly higher leaf-stem ratio in maize + soybean, might be due to favourable nitrogen supply by soybean resulting in increase in number and size of leaves leading to higher leaf stem ratio. Any agronomic practice that positively influences leaf-stem ratio should be greatly encouraged as it is very vital forage quality index since leaves have much higher feeding value than stems. Ike *et al*., 2013 and Ginwal *et al.*, 2019 [12] reported higher leaf-stem ratio with maize-legume intercropping over sole maize.

Among zinc levels, Zn2 recorded highest leaf-stem ratio in case of maize (0.47 and 0.49) and legumes (0.46 and 0.48) compared to Zn1 and Zn0 during the two years. The increase in growth parameters like leaf stem ratio could be due to role of zinc in auxin metabolism, leading to higher hormonal activity and growth performance. Bhoya *et al.*, 2013 also reported an increase in leaf stem ratio of fodder sorghum from 0.36 to 0.40 as zinc fertilizer was increased from 0 to 4 kg ha^{-1}. Kumar *et al*., 2014 and Kumar *et al*., 2016b also reported similar results.

3.4 Dry matter accumulation

The perusal of the data (table 1) revealed that dry matter accumulation of maize varied significantly with the cropping system. Sole maize recorded highest dry matter 116.11 q ha^{-1} (2020) and 122.67 q ha^{-1} (2021) followed by maize in maize + soybean intercropping. Among the legumes, sole soybean recorded significantly higher dry matter (55.05 and 58.92 q ha^{-1}) compared to cowpea (44.78 and 47.88 q ha^{-1}) at harvesting stage during both the years (table 2). With respect to total dry matter (maize + legume), sole maize recorded highest dry matter (116.11 and 122.67 q ha^{-1}) followed by maize + soybean (105.77 and 111.79 q ha^{-1}), maize + cowpea (99.41 and 106.80 q ha^{-1}), sole soybean (55.06 and 58.92 q ha^{-1}) and sole cowpea (44.78 and 47.89 q ha^{-1}). Dry matter accumulation is an important character to express the growth and metabolic efficiency of the plant, which ultimately influences the yield. Higher dry matter accumulation with sole planting of maize may be attributed to higher plant population per hectare and higher production potential of maize as compared to legumes. In other words, lesser dry matter accumulation in intercropping systems was due to the replacement series of intercropping and also suppressing ability of maize on cowpea and soybean. The present findings are in agreement with the results of Javanmard *et al*., 2009 [16], Takele *et al*., 2017 [28]; Choudhary *et al*., 2012b [10]; and Kour *et al*. 2016 [18].

Zinc fertilization significantly increased dry matter accumulation in all the cropping systems. In case of maize based systems, highest dry matter at harvesting was recorded with Zn2 (104.11 and 109.22 q ha^{-1}) during 2020 and 2021 respectively, and lowest in Zn0 (84.67 and 89.33 q ha^{-1}) during the two years, respectively. Legumes also recorded highest dry matter (42.78 and 45.95 q ha^{-1}) with Zn2 and lowest (23.29 and 26.54 q ha^{-1}) in control (Zn0). Higher dry matter with zinc application may be attributed to activation of various enzymatic reactions, improved photosynthesis and carbohydrate assimilate partitioning from source to sink. The present findings are in agreement with the results of Kumar *et al*., 2016a [20]; Kumar *et al*., 2016b [21]; Kumar and Bohra, 2014 [19]; Bhoya *et al*., 2013 and Kumar and Ram, 2021 [22].

Table 1: Effect of different cropping systems and zinc levels on growth parameters of maize

Treatment	Plant height (cm)		Leaf area index		Leaf stem ratio		Dry matter accumulation (q ha^{-1})	
	2020	2021	2020	2021	2020	2021	2020	2021
Cropping system								
Maize	255.00	256.12	5.57	5.59	0.44	0.45	116.11	122.67
Maize +Cowpea	256.13	261.84	5.63	5.63	0.45	0.47	83.89	88.68
Maize +Soybean	257.85	263.81	5.66	5.69	0.45	0.48	86.44	89.77
SE(m) ±	1.05	1.08	0.02	0.11	0.01	0.01	1.18	1.12
C.D. (p≤0.05)	NS	NS	NS	NS	NS	NS	3.55	3.37
Zinc								
Zn0	243.11	244.58	5.53	5.55	0.41	0.44	84.67	89.33
Zn1	255.60	256.33	5.65	5.67	0.47	0.47	97.66	102.58
Zn2	263.27	266.07	5.72	5.75	0.47	0.49	104.11	109.22
SE(m) ±	1.05	1.08	0.02	0.01	0.01	0.01	1.18	1.12
C.D. (p≤0.05)	3.16	3.25	0.05	0.04	0.02	0.02	3.53	3.38

Table 2: Effect of different cropping systems and zinc levels on growth parameters of legumes

Treatment	Plant height (cm)		Leaf area index		Leaf-stem ratio		Dry matter accumulation (q ha^{-1})	
	2020	2021	2020	2021	2020	2021	2020	2021
Cropping system								
Cowpea	118.4	119.3	3.56	3.58	0.41	0.46	44.78	47.88
Soybean	129.1	130.3	3.80	3.81	0.45	0.42	55.05	58.92
Maize + cowpea	115.0	117.2	3.52	3.54	0.41	0.45	15.52	18.10
Maize +Soybean	124.0	128.6	3.76	3.77	0.01	0.41	19.32	22.01
SE(m) ±	0.76	0.85	0.01	0.04	0.02	0.01	1.42	1.22
C.D. (p≤0.05)	2.22	2.49	0.04	0.11	0.41	0.02	4.16	3.59
Zinc								
Zn0	115.9	116.4	3.64	3.64	0.41	0.41	23.29	26.54
Zn1	125.0	126.1	3.69	3.72	0.44	0.47	34.94	37.71
Zn2	129.1	132.2	3.72	3.76	0.46	0.48	42.78	45.95
SE(m) ±	0.65	0.74	0.01	0.03	0.00	0.01	1.23	1.22
C.D. (p≤0.05)	1.92	2.16	0.03	0.09	0.01	0.02	3.60	3.59

4. Conclusions

The results of two year field experiments indicated that intercropping of maize with cowpea and legumes improved growth parameters of maize, however, sole planting of maize recorded highest dry matter 116.11 q ha^{-1} (2020) and 122.67 q ha^{-1} (2021) followed by maize in maize + soybean intercropping. Both the intercropped treatments significantly improved dry matter production over sole legume treatments but maize + soybean resulted significantly higher dry matter production over maize + cowpea intercropping. Soil + foliar application (Zn2) recorded significantly higher dry matter over control (Zn0) both in maize (104.11 and 109.22 q ha^{-1}) as well as legume (42.78 and 45.95 q ha^{-1}) based systems during 2020 and 2021 respectively. Hence for higher growth and subsequently fodder yield, soil (20 kg $ZnSO_4$ ha^{-1}) + foliar application ($ZnSO_4$ @ 0.5% twice) of zinc should be followed in maize + soybean intercropping system.

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