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EFFECT OF NANO-NPK AND CHEMICAL FERTILIZERS ON THE GROWTH, YIELD ATTRIBUTES, AND YIELD OF SOLE AND INTERCROP MAIZE IN PUNJAB.

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Abstract

An experiment was conducted to ascertain the effects of nano NPK fertilizers and chemical fertilizers on sole maize and intercrop maize growth and yield characteristics at the Lovely Professional University, Punjab agricultural farm. Eight treatments and three replications were used in the split-plot design experiment, which used a cropping system as the main plot and fertilizers as subplots. The intercropping of maize and mungbean produced significantly higher mean values for the number (no.) of leaves, leaf area index (LAI), cob length, cob diameter, cob weight, no. of cobs per plant, no. of grains per cob, test weight (1000 seed weight in g), grain yield, straw yield, biological yield, and harvest index, as compared to the sole maize on the main plot. Furthermore, in the subplot, the combination of nano NPK and Recommended dose of fertilizers (RDF) considerably enhanced maize growth, yield characteristics, and yield in comparison to the other treatments. This study found that the most efficient way to boost crop growth and yield is by intercropping maize with mungbean + 50 % RDF + 50 % NPK nano fertilizers.

Keywords: Growth, Intercropping, Maize, Nano-fertilizers, Yield, Yield Attributes

1. INTRODUCTION

The queen of cereal grains, maize (*Zea mays* L.), was developed in Central America. Currently, it ranks as the third-most significant cereal crop worldwide. Due to maize's high adaptability, farmers have created a variety of genetic resources with diverse adaptations, characteristics, and uses [1]. It can also be used in livestock feed, making starch, glucose, and cornflakes [2]. Due to its low chemical nutrient requirements, it can be cultivated in any type of soil. Uttar Pradesh, Rajasthan, Madhya Pradesh, Bihar, Himachal Pradesh, Jammu and Kashmir, and Punjab are the top-producing states for maize in India [3]. In Punjab, maize can be a key component of crop diversity [2]. A total of 107.8 thousand hectares of maize were sown in Punjab State in 2020-21, producing 395.1 thousand tons. The average per hectare was 36.65 quintals (14.83 per acre) [4].

Undoubtedly, the rice–wheat cropping system is one of the most significant aspects of Indian farming, especially in the northwestern region. However, the continuous implementation of this cropping system in northwest India has resulted in significant challenges for this system and stagnant productivity [5,6]. There are several emerging problems that threaten its sustainability, including the exhaustion of soil nutrient reserves, deteriorated soil health, water depletion, an escalating production cost, a scarcity of labor, an increase in greenhouse gas emissions due to crop residue burning, climate vulnerabilities, and herbicide resistance in weeds [7,8]. Farmers can overcome most of these challenges by cultivating maize which can conserve 90 % of water and get more income than wheat and paddy. Furthermore, the maturity period is shorter compared to wheat and paddy [9].

Intercropping is one of the most promising methods for increasing crop productivity in sub-tropical Asia [10,11], where smallholder farmers have limited land resources and low crop productivity. Intercropping systems cultivate two or more crops consecutively with separate row arrangements for complementary use of natural resources, increasing production [12]. Leguminous crops are beneficial to intercropping because they transfer fixed nitrogen to the associated crop, which in this case is maize. Intercropping with leguminous crops also mitigates drought and provides early-stage canopy cover because legumes act as live mulch, which lowers soil erosion and evaporation. Additionally, it eliminates weeds and lessens the farmer's labor requirements [11].

Due to erosion, environmental degradation, unintended irrigation, and fertilizing, agricultural land is decreasing day by day. However, agricultural productivity must be increased to meet the demands of the expanding population and the needs of the burgeoning industry. The use of nanofertilizers has become more prevalent in recent years, to increase the amount and quality of production from each unit area. The use of nano fertilizers in agriculture increases crop yield and nutrient efficiency and reduces the use of excessive chemical fertilizers. In addition to containing macro and micronutrients, these fertilizers can be applied frequently in small amounts and are environmentally friendly [13]. Although many studies have been conducted to increase maize yield, just a few uses of NPK nanofertilizers are reported in the literature in India, particularly in the Punjab area. Therefore, this study is aimed to investigate whether sole maize and intercrop maize would respond to granular and foliar environmentally friendly Nano-NPK fertilizers when adapted to Punjab-specific crop production conditions.

2. MATERIAL AND METHODS

2.1 Study area

The study for this research was performed on the agricultural farm of Lovely Professional University, Department of Agronomy. At an elevation of 249 m above mean sea level, the experimental location was situated at 31.2560° N latitude and 75.7051° E longitude. The experimental site is in the subtropics, with mild winters, scorching summers, and occasional wet spells in July, August, and September. The southwest monsoon is the main source of rain.

2.2 Materials

In the present study, seeds of maize were obtained from Lovely Professional University, Punjab. During the current study, ultra-pure chemicals and reagents were used and were obtained from standard chemical companies.

2.3 Experimental design and treatments

The experiment was designed as split plots and repeated three times in a plot size of 40 m x 15m (600m^2). The experiment included eight treatments viz.,1) Main plot; -M_1-Maize (sole cropping); M_2-Maize+Mungbean (intercropping) and 2) Subplot; - S_1: Control; S_2: 100 % RDF; S_3:100 % nano NPK fertilizers; S_4: 50 % RDF + 50 % nano NPK fertilizers. The recommended fertilizer doses were applied @ 50 kg/acre N, 25 kg/acre P_20_5, and 12 kg/acre K in maize, while in mungbean 5kg/acre N, 16 kg/acre P_20_5, and 0 kg/acre K respectively. As chemical sources of fertilizer, urea, diammonium phosphate, and muriate of potash were used. Nano NPK (19:19:19) was used as nano fertilizer and applied as a foliar application with doses @ 2g/litre.

2.4. Measurement of growth parameters, yield, and yield attributes

At 30, 60, and 90 Days after sowing (DAS), the plant height, no. of leaves, and leaf area index were all measured. While yield characteristics such as the cob length (cm), cob girth (cm), cob weight (g), no. of cobs per plant, no. of grains per cob, test weight(g), grain yield (t/ha), straw yield (t/ha), biological yield(t/ha), and harvest index were determined at harvest.

2.5. Statistical analysis

Using the star (statistical tool for agriculture) software package, an analysis of variance (ANOVA) was performed on all the obtained data. Duncan's multiple test range was applied to separate the means that are statistically significant ($P \leq 0.05$).

3. RESULTS

3.1. Growth Parameters

The current study emphasizes the impact of various fertilizer dosages on sole maize and intercrop maize growth metrics. Data in Table 1 revealed that the height of the plant gradually rose up to the end of the study period at 30, 60, and 90 DAS as the plant approaches maturity. Maximum maize plant height was recorded when maize was intercropped with mungbean while minimum plant height was recorded with maize as the sole crop at all sampling periods. The plot treated with 50% RDF + 50% nano NPK fertilizers had the maximum plant height among the various fertilizer applications, and it was statistically comparable to the 100% recommended dose of NPK application but considerably superior to the other treatments at 30 and 90DAS, while at 60DAS, the highest plant height was observed in 50 % RDF + 50 % nano NPK fertilizers followed by 100% RDF of NPK application; 100% nano NPK fertilizers and the lowest plant height was observed in control (Table1).

The intercropping of maize and mungbean produced the most leaves per plant during all sample periods, while maize grown as a sole crop produced the fewest leaves per plant. Application of 50% RDF +50% Nano-NPK fertilizers to maize has produced the highest no. of leaves per plant at 30 and 90 DAS. Plot treated with 50% RDF +50% Nano-NPK fertilizers and 100 % RDF of NPK application had a higher mean value than the other treatments at 60 DAS. At every level of sampling, the control consistently recorded the fewest leaves per plant (Table 1).

At all stages of sampling, the intercropped maize had a greater leaf area index (LAI) than the sole maize. In different levels of fertilizers treatments at 30DAS, 50% RDF +50% Nano-NPK fertilizers had the highest lAI accompanied by 100% RDF and 100% Nano NPK fertilizers which are at par statistically but significantly higher than the control. At 60 and 90DAS, 50% RDF +50%

Nano-NPK fertilizers had a higher LAI mean value that was comparable with 100% RDF but significantly higher than 100% Nano NPK fertilizers and control.

3.2. Yield attributes

Intercropping of maize and mungbean had no significant impact on the length of the maize cob, while different levels of fertilizer treatments had a considerable impact (Table 2). Among the different levels of fertilizer treatments, the application of 50 % RDF+50 % Nano-NPK fertilizers to maize resulted in a longer cob length, which is statistically at par with that of 100 % RDF, and both are significantly higher than the other treatments (Table 2).

Maximum cob diameter and cob weight were noticed when the maize was intercropped with mungbean while the minimum was recorded in sole maize. Among the different levels of fertilizer, the application of 50% RDF+50% Nano-NPK fertilizers to maize resulted in the highest cob diameter and cob weight which was significantly superior to all other levels of fertilizer application. The lowest cob diameter and cob weight were recorded in the control (Table 2 and fig.1).

Compared to different levels of fertilizer treatments on maize, intercrop maize and sole maize had no significant impact on the no. of cobs per plant. Among the different levels of fertilizer applied, 50% RDF+50% Nano-NPK fertilizers and 100% RDF resulted in a higher no. of cobs per plant than the 100% RDF and control (Table 2).

A significantly highest number of grains per cob was noticed when the maize was intercropped with mungbean, while the lowest number of grains per cob was noted in the sole maize crop. The application of 50% RDF+ 50% Nano-NPK fertilizers to maize produced a greater no. of grains per cob, which was on par with the 100% RDF, and both were much better than the rest of the treatment (Table 2).

Test weight as impacted by maize + mungbean intercropping and different levels of fertilizer management practices is presented in Table 3. The highest test weight was recorded when the maize was intercropped with mungbean while the lowest was recorded in the sole maize. In fertilizer treatments, the application of 50% RDF+50% Nano-NPK fertilizers to maize resulted in a higher test weight followed by a 100% recommended dose of fertilizer application, 100 percent NPK nano fertilizers, and control had the lowest test weight (Table 2).

3.3 Yield

The highest mean value for grain yield, straw yield, biological yield, and Harvest index was recorded in maize + mungbean intercrop, and the least was recorded in sole maize. Significantly, the highest mean value for yield and harvest index were found in 50% RDF+50% Nano-NPK fertilizers followed by 100 percent RDF,100 percent NPK nano fertilizers, and control in fertilizer treatments (Fig.2 and 3).

4. DISCUSSION

4.1. Response of maize to the cropping system

Findings revealed that growth parameters were found maximum when maize was intercropped with mungbean rather than when grown alone except in plant height which was not significant. The no. of leaves and lAI of maize increased progressively up to 60DAS and declined thereafter up to harvest. The possible reason can be due to the transition of maize from vegetative to reproductive stages. The significant increase in LAI and the no. of leaves in maize-mungbean intercrop could be attributed to the efficient utilization of growth resources *viz* moisture, light, and nutrients coupled with legume's ability to convert inorganic nitrogen to a state that the plant can be absorbed by fixing nitrogen from the atmosphere. This result agrees with the findings of [14], who reported an increase in light interception, reduction of water loss, and improved soil moisture conservation in intercrop maize. Also, [15,16] reported a significant increase in leaf area index in maize-legume intercrop due to the complementary effect between base crop and intercrop.[17], also found higher LAI when maize was intercropped with mungbean.

The yield attributes viz cob length, cob diameter, cob weight, no. of cobs per plant, no. of grains per cob, test weight, grain yield, straw yield, biological yield, and harvest index (%) was also higher with intercrop than the sole cropping. The possible reason for that is the intercrop's ability to utilize growth and yield resources more efficiently and convert them into crop biomass, leading to higher yield production. In addition, the legume fixes atmospheric nitrogen, which supplies additional nitrogen for the component crop, leading to high dry matter production and grain yield other than the sole crop maize. These outcomes agree with that of [18], who stated that a general increase in the yield of maize-legume intercrop was due to an increase in the fertility of the soil by the legume. [19,20] also found an increase in the yield of maize+ legumes intercropping compared to the sole maize. Similar findings were reported by [21, 22, 23].

4.2. Responses of maize to different levels of fertilizers

As shown in tables 1 and 2, the growth attributes such as plant height, no. of leaves, and LAI were all significantly highest in the S_4 treatment (50 percent RDF + 50 percent Nano NPK fertilizers) than in the other treatments. This could be attributed to nano fertilizers' ability to supply major essential nutrients faster to cells via foliar spraying through stomata or wounds and scratches in the leaves, which enhances the speed and uniformity of nutrient delivery for plant metabolisms and promotes maize growth attributes. The outcome is consistent with the research findings of [24], who reported an increase in growth attributes due to faster delivery of nano fertilizers nutrients via foliar spraying. Similarly, [25,26,27,28,29] also found a significant increase in vegetative growth parameters after using nano fertilizer. Also, [30] found that the combined application of nano fertilizer significantly increased the height of the maize plants due to nano fertilizer's ability to provide nutrients or aid in the transportation and absorption of available nutrients, leading to better crop growth. A significant increase in wheat leaf area index was observed when nano fertilizers were applied to maize via foliar spray [31].

Higher yield components, such as cob length, cob diameter, cob weight, no. of cobs per plant, no. of grains per cob, test weight, grain yield, straw yield, biological yield, and harvest index of maize were observed in 50 percent RDF + 50 percent Nano NPK fertilizers during the research trial were as a result of maize ability to utilize essential nutrients supplied by the RDF at the early growth stage coupled with the nutrients supplied by the Nano-NPK fertilizers via foliar spray at the later stages which also aid in the plant's uptake of water and nutrient, improved the photosynthesis process, hence, leading to the production of high dry matter. This concurs with the findings of [32], who found a synergistic effect between traditional fertilizer and nano fertilizers for higher nutrient uptake in the cells of the plant which led to increased photosynthesis resulting in the accumulation of higher photosynthates, and transportation of nutrients to the economic parts of the plant which correlate in a final grain yield. Additionally, the results were similar to those found by [25,27], who found that nano fertilizers significantly impacted yield components. The present study's results agree with [33,34] who found that applying nano-fertilizers by foliar spraying enhanced wheat yield and yield components.

Table 1: Impact of different levels of fertilizers on the growth parameters of sole and intercrop maize.

Treatments	**Plant height(cm)**			**No. of leaves**			**Leaf area index**		
	30DAS	**60DAS**	**90DAS**	**30DAS**	**60DAS**	**90DAS**	**30DAS**	**60DAS**	**90DAS**
A. Main Plot									
M_1	27.22	131.73	203.33	5.42^{b}	12.71^{b}	11.59^{b}	1.04^{b}	3.49^{b}	2.77^{b}
M_2	35.10	155.25	220.97	6.76^{a}	13.60^{a}	12.65^{a}	1.39^{a}	5.14^{a}	3.14^{a}
SEm (±)	1.39	7.19	3.52	0.06	0.08	0.08	0.01	0.10	0.02
CD (0.05%)	NS	NS	NS	0.40	0.50	0.54	0.08	0.63	0.13
B. Sub Plot									
S_1	20.95^{c}	105.50^{c}	169.33^{c}	4.84^{d}	10.88^{c}	9.05^{d}	0.74^{c}	3.05^{c}	2.07^{c}
S_2	34.19^{ab}	153.35^{b}	222.5^{ab}	6.49^{b}	12.68^{a}	12.06^{b}	1.35^{b}	4.81^{a}	3.31^{a}
S_3	31.90^{b}	142.37^{b}	211.50^{b}	5.95^{c}	11.76^{b}	10.87^{c}	1.21^{b}	4.41^{b}	2.92^{b}
S_4	37.61^{a}	172.75^{a}	243.16^{a}	7.07^{a}	13.71^{a}	12.59^{a}	1.56^{a}	5.00^{a}	3.51^{a}
SEm (±)	1.21	4.63	9.17	0.07	0.19	0.17	0.05	0.08	0.07
CD (0.05%)	3.78	14.41	28.56	0.20	0.59	0.53	0.15	0.26	0.23

Table 2: Impact of different levels of fertilizers on yield attributes of the sole and intercrop maize.

Treatments	**Cob length (cm)**	**Cob diameter (cm)**	**Cob weight(g)**	**No. of cobs per plant**	**No. of grains per cob**	**Test weight (g)**
A. Main Plot						
M_1	21.85	9.42^{b}	296.25^{b}	1.25	465.58^{b}	31.25^{b}

M_2	23.75	10.25[a]	339.17[a]	1.42	559.50[a]	41.64[a]
SEm (±)	0.50	0.09	3.08	0.21	1.36	0.32
CD (0.05%)	NS	0.55	20.15	NS	8.90	2.11
B. Sub Plot						
S_1	19.35[c]	8.42[d]	207.50[d]	1.00[b]	344.50[c]	29.90[d]
S_2	24.82[a]	10.20[b]	356.67[b]	1.47[a]	589.00[a]	40.90[b]
S_3	22.08[b]	9.45[c]	320.00[c]	1.20[b]	508.50[b]	33.03[c]
S_4	24.95[a]	11.27[a]	386.67[a]	1.67[a]	608.17[a]	41.95[a]
SEm±	0.38	0.15	3.31	0.11	5.06	0.23
CD (0.05%)	1.17	0.46	10.30	0.36	15.77	0.72

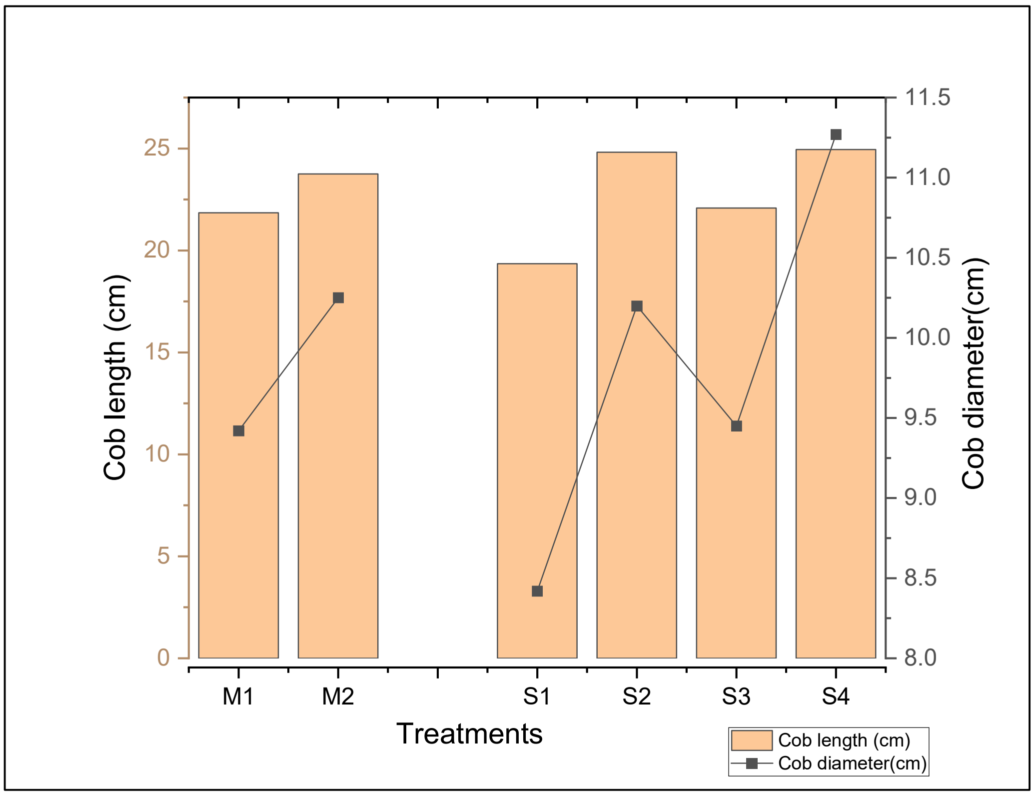

Fig. 1. Effect of different levels of fertilizers on the cob length and cob diameter of sole and intercrop maize.

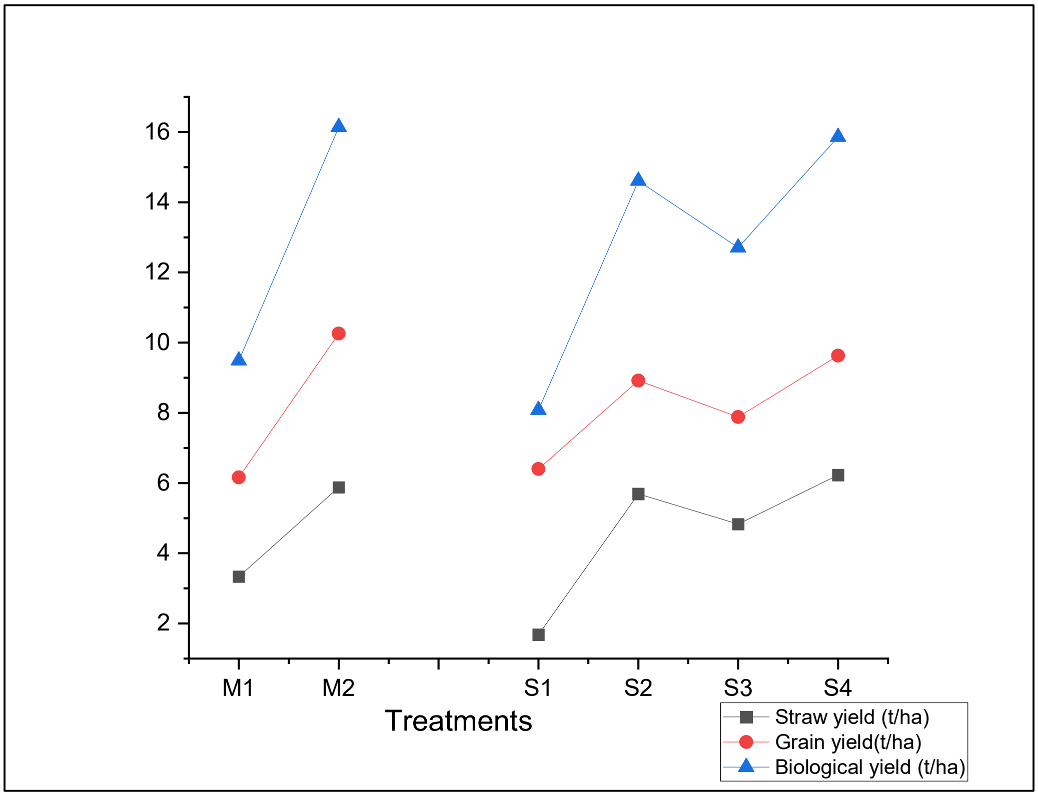

Fig. 2. Effect of different levels of fertilizers on the yield of sole and intercrop maize.

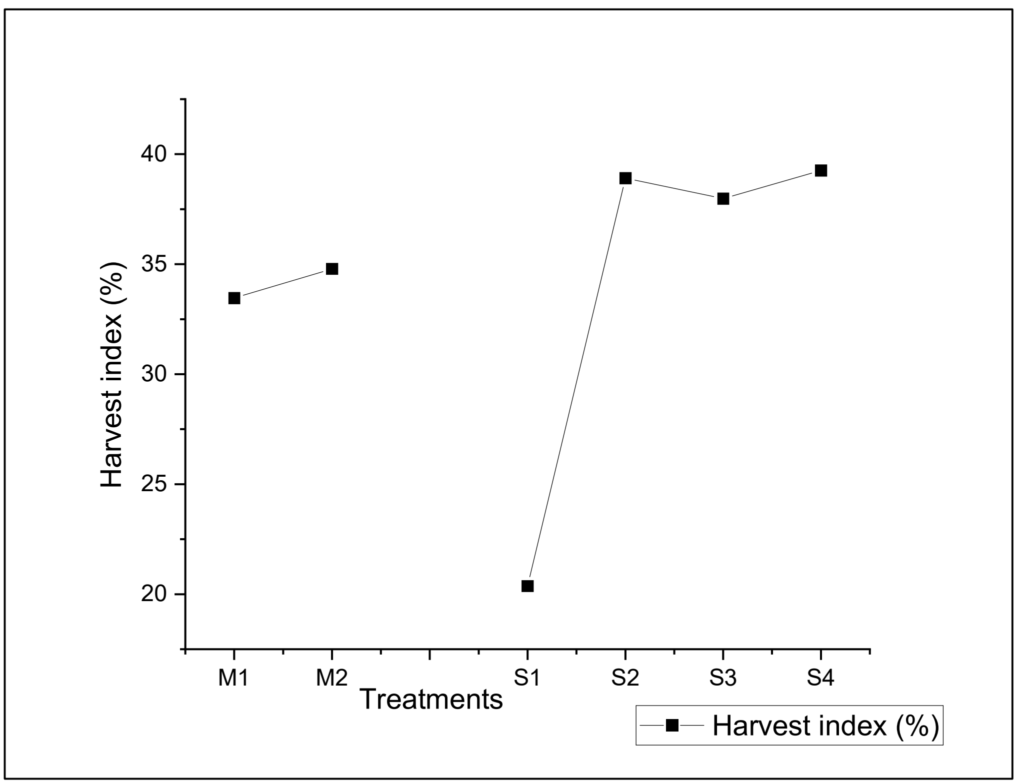

Fig. 3. Effect of different levels of fertilizers on the harvest index (%) of sole and intercrop maize.

Note: Data is in the form of Mean ± SEm, S =Significance at P≤0.05, NS= Non-Significant at P≤0.05, CD= Critical difference, Means followed by different letters are statically different at 0.05%, M_1 = Sole maize, M_2=Sole maize intercrop with mungbean, S_1: Control (no fertilizer); S_2: 100 % RDF; S_3:100 % NPK nano fertilizers; S_4:50 % RDF+50 % NPK nanofertilizers.

5. CONCLUSION

The present research shows that foliar sprays of NPK nano fertilizers affect maize growth, leading to favorable changes in growth, yield attributes, and yield. It was evident that 50 % RDF and 50 % NPK nano fertilizers are the most effective fertilizers for boosting both maize growth, yield attributes, and yield. In general, we can infer that NPK nano fertilizers may be a good substitute for chemical NPK fertilizers in sustainable development. Excessive fertilizers used to boost crop productivity do not always result in higher yields; instead, it often endangers human health and causes major environmental issues. Our findings could help other studies researching nano fertilizer applications in agriculture. Foliar use of nano fertilizers can open up new avenues in agricultural practices as nanoparticle fertilization looks to be a safe way to enhance nutrient levels in plants without harming the environment. Nonetheless, further field research is needed to investigate various agrochemicals' effects on plant development and metabolism, as well as plants treated with nanoparticles that are intended for use by animals, need to be tested for safety.

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