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Effect of Seed Priming and Fertilizer Levels on Growth, Yield Attributes and Yield of *Rabi* Maize

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The present investigation was conducted during the *rabi* season of 2019-20 at College of Agriculture, Navsari Agricultural University, Navsari to study the "Effect of seed priming and fertilizer levels on *rabi* maize under south Gujarat condition". The experiment was laid out in Randomized

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Block Design with factorial concept (FRBD) with ten treatment combinations consisting of two factors which consists seed priming, Control (No priming), Seed priming with water for 12 hrs., Seed priming with 0.5% KCl for 12 hrs., Seed priming with 0.5% $KMnO_4$ for 12 hrs., Seed priming with 0.5% KH_2PO_4 for 12 hrs and fertilizer levels, 75% RDF (112.5+45+00, N: P_2O_5: K_2O kg/ha) and 100 Recommended dose of fertilizers (RDF) (150+60+00, N: P_2O_5: K_2O kg/ha). Treatments are replicated three times. The result indicated Seed priming with 0.5% KH_2PO_4 for 12 hrs recorded significantly higher plant population, number of leaves per plant, plant height, grain and straw yield compared to other treatments. In case of fertilizer levels number of leaves per plant and plant height recorded non significant at 30 DAS. Significantly higher plant height at 60 DAS, 90 DAS, at harvest, grain and straw yield recorded in treatment of 100% RDF (150+60+00, N: P_2O_5: K_2O kg/ha). Treatment combination S5F2: (KH_2PO_4 at 0.5% for 12 hrs with 100% RDF i.e., 150+60+00, N: P_2O_5: K_2O kg/ha) recorded significantly higher plant height at 90 DAS, at harvest, Grain and straw yield as compared to other treatments. Thus a combination of Seed priming 0.5% KH_2PO_4 for 12 hrs with 100% RDF (150+60+00, N: P_2O_5: K_2O kg/ha) helps in enhancing the growth parameters, yield attributes and yield of *rabi* maize without negative influence on plant and the environment.

Keywords: Seed priming; fertilizer; yield and maize.

1. INTRODUCTION

Maize (*Zea mays* L.) is an important cereal crop globally after wheat and rice. The importance of maize lies in its wide industrial applications besides use as sustenance for humans and animals. Among the food grain crops it is the most versatile crop with wider adaptability in diverse agro-ecologies and has highest yield potential [1,2,3]. Due to its numerous applications in the food, feed and industrial sector, maize is becoming more and more demand worldwide. Consequently, we must produce more with the same or even less resources [4].

Although maize is mainly a *kharif* season crop but in recent years *rabi* maize has gained a significant place in total maize production in India. In Gujarat state maize is grown in 2.82 lakh ha in kharif and 1.11 lakh ha in winter *rabi* with production of 8.26 lakh tones and productivity 2098 kg/ha during the year 2023-24 (indiastat.com) [5]. In India, 9.75 million tonnes of grain are produce from 1.75 million ha of *rabi* maize, with an average productivity rate of 5555kg/ha during the year 2023-2024 (indiastat.com) [5]. In world wide area and production of maize is about 197.18 million ha and 1134.70 million tonnes, respectively with productivity of about 5755 kg/ha during the year 2017-18 [6].

Germination and seedling emergence are the critical stages in the plant life cycle. In south Gujarat condition soil crust problems are prevalent due to these problem insufficient seedling emergence and inappropriate stand establishment are the main constraints in the production of crops which receiving less amount of rainfall. Among the various agronomic factor, seed priming is important factor for enhancing germination, seedling emergence and yield of *rabi* maize. Seed priming is a useful treatment, applied prior to planting, one method of seed priming is uncontrolled hydration- hydro priming another method is osmo-priming which involves the use of adverse osmotic solutions, like different salts such as KCl, KNO_3 and KH_2PO_4 etc. [7]. There are various factors that influence rabi maize productivity, but nutrient management is one of the most essential in terms of maize growth and yield. Maize is an exhaustive crop which requires a wide range of macro and micro nutrients to achieve optimal growth and yield potential.

2. MATERIALS AND METHODS

2.1 Description of Experiment Site

The field experiment was carried out at B-block of Agronomy Farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari during *rabi* season of 2019-20. That located at 200 57' N latitude and 720 54' E longitudes at an altitude of 10 meters above the mean sea level. This region's climate is characterized by a reasonably hot summer, a relatively cold winter, and a warm humid monsoon with heavy rainfall. According to Fig. 2 the maximum temperature ranged from 27.4 0 to 34.4 ^{0} C, while lowest temperature ranged from 8.4 ^{0} to 19.3 ^{0}C during *rabi* 2019-20. The data showed (Fig. 2) that during summer 2019-20, the maximum relative humidity ranged from 76.4 to 90.2 %, while minimum relative humidity from between 39.4 to 68.6 %. The meteorological data showed that the weather conditions throughout the growing season were suitable for satisfactory growth and development of *rabi* maize. The winter season normally starts in the first week of November and lasts until the middle of February. The soil of the experimental plot was alkaline in reaction and the dry soil was dark brown with textured clay.

2.2 Treatments and Experimental Design

The experiment were conducted in the FRBD which consists two factors Factor I- Seed priming (S) S1: Control (No priming), S2: Seed priming with water for 12 hrs, S3: Seed priming with 0.5% KCl for 12 hrs, S4: Seed priming with 0.5% $KMnO_4$ for 12 hrs and S5: Seed priming with 0.5% KH_2PO_4 for 12 hrs. Factor II- Fertilizer levels (F) F1: 75% RDF (112.5+45+00 N: P_2O_5: K_2O kg/ha) F2: 100% RDF (150+60+00 N: P_2O_5: K_2O kg/ha) with three replication. The total treatment combination was ten which is S1F1, S1F2, S2F1, S2F2, S3F1, S3F2, S4F1, S4F2, S5F1 and S5F2. The net plot size of the experiment was 3.6 m × 4 m and gross plot size 6.0 m ×5.0 m. Common application of Bio compost 5 t/ha in every treatment combination.

2.3 Experimental Procedures and Field Management

The experiment was executed at B-block of Agronomy Farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari during *rabi* season of 2019-20 and used of three chemicals (KCl, $KMnO_4$ and KH_2PO_4) used for seed priming. The solution of these chemicals prepares by dissolving 5g (of each chemical) per liter of distilled water separately to make 0.5% solution beside this treatment only water treatment also given with same quantity of water. Seed of *rabi* maize were soaked in prepared solution of all the chemicals separately for 12 hrs after soaking the seed were dried in shade until seed coat become dry [8]. The total amount of phosphorus and half amount of nitrogen were applied as basal dose and remaining half dose of nitrogen given as a split application after three weeks of sowing. The nutrients were applied in the form of urea (46% N) and single super phosphate (16% P_2O_5) with dose 150+60+00 N: P_2O_5: K_2O kg/ha by the method of band placement with different dose according to treatment

The field was prepared using a tractor drawn M.B. plough and planking and experiment was laid out according to the layout plan. Recommended seed rate of 20 kg/ha was used for sowing. Plot wise quantity of seed was weighted and applied different priming techniques as per treatment before sowing and sown manually at the depth of 4-5 cm by line sowing. Irrigations were given five times. First irrigation was given just after sowing to ensure optimum germination. For effective weed control, one hand weeding was carried out at 30 DAS with inter cultivation with mechanical weeder. Overall, the crop stand was satisfactory and there were no instances of insect and disease attacks, so general application of Carbofuran 3G @15 kg/ha at 20 DAS was taken against maize stem borer.

2.4 Data Collected and Collecting Procedure

The initial and at harvest plant population counts were obtained by counting the total number of plants that emerged in net plot. The plant population was counted at 20 days after sowing and at harvest converted on hectare basis. To determine the number of leaves per plant, all green and developed leaves from five randomly selected and tagged plants were counted at 30, 60, 90 DAS and harvest. The height of five previously randomly selected and tagged plants was measured from the base to the tip of main shoot at 30, 60, 90 DAS, as well as at crop harvest. The mean plant height was computed and given in cm. The days required from sowing to achieve 50 per cent flowering were recorded for each treatment separately by considering 50% flowered plants from net plot. Five cobs from the five tagged plants were utilised to determine cob length. The lengths of the five cobs were measured in cm from the bottom to the tip and mean values were recorded. The girth was measured using the same five cobs that were used to assess the cob length. The girth was measured in cm from the top, middle and bottom of the cobs. Cobs from all the plants in each net plot were harvested separately and sun dried for around 10 days. After the cobs had completely dried, the grains were separated from them using wooden sticks. The produce obtained in this way was cleaned and weighed. The total grain weight per plot was calculated by summing the grain weight of five sample plants and then converting to hectare basis. After harvesting the cobs, from the plants, the plants were harvested from the net plot separately and allowed to sun dried in the field for roughly 10 days. Then it was tied into bundles of appropriate size and straw yield per net plot was recorded. The total straw yield per net plot was calculated by adding the straw weight of five sample plants and then converting to hectare basis.

3. RESULTS AND DISSCUTION

3.1 Plant Population

Significantly higher plant population (Table 1) was recorded at 20 DAS and at harvest with the treatment of S5 (79017 and 79007/ha, respectively) which was remained at par with treatment S3 (78856 and 78842/ha, respectively) whereas, significantly lowest plant population was recorded at 20 DAS and at harvest with control treatment (No priming) (76614 and 76590/ha, respectively). Higher plant population might be due to the fact that KH_2PO_4 have been introduced as the osmotica which has shown promising results in improving emergence, germination and better stand establishment. KH_2PO_4 showed a relatively beneficial effect apparently because phosphorous reserves in the seed play significant role in the metabolism of germinating seed. These results are in consistent with the findings of Toklu et al. [9]. The plant population recorded at 20 days after sowing (DAS) and at harvest didn't show significant differences across various fertilizer levels. However, there was a noticeable increase in plant population at both 20 DAS and harvest with treatment F2 compared to treatment F1. Specifically, treatment F2 demonstrated higher plant populations of 78080 and 78064 per hectare at 20 DAS and harvest, respectively.

3.2 No. of Leaves Per Plant

The data given in Table 1 indicated that No. of leaves per plant recorded at 30 DAS, 60 DAS, 90 DAS and at harvest were significantly affected by various seed priming treatments. Significantly higher No. of leaves per plant was recorded at 30 DAS, 60 DAS, 90 DAS and at harvest with the treatment of S5 (10.13, 12.82, 13.07 and 12.63/plant, respectively) which was remained at par with S3 (8.95, 11.47, 11.99 and 11.63/plant, respectively). Significantly higher No. of leaves per plant could be attributed due to rapid and uniform emergence and higher vigour of seedlings Banerjee et al. [10]. No. of leaves per plant recorded at 30 DAS were found non-significant with fertilizer levels and at 60 DAS, 90 DAS and at harvest (12.82, 13.07 and 12.63/plant, respectively) were significantly influenced by different fertilizer levels. Significantly the highest No. of leaves per plant was recorded with application of treatment F2 at 60 DAS, 90 DAS and at harvest as compared to treatment F1. The increase no. of leaves per plant might due to higher availability of Nitrogen and Phosphorus Thorat et al. [11].

3.3 Plant Height (cm)

A data given in (Table 1) indicated that plant height (cm) recorded at 30 DAS, 60 DAS, 90 DAS and at harvest were significantly influenced by various seed priming treatments. Significantly higher Plant height (cm) was recorded at 30 DAS, 60 DAS, 90 DAS and at harvest with the treatment of S5 (75.27, 145.43, 185.15 and 186.9 cm, respectively) which was remained at par with treatment S3 (71.72, 136.43, 179.99 and 181.63 cm, respectively) and plant height also at 30 DAS at par with treatment S4 (70.33 cm). Bhowmick et al. [12] found that KH_2PO_4 solution and priming have several positive effects on seed germination and seedling growth. These effects include improved germination rates, reduced lipid peroxidation, enhanced antioxidative activity, and overall better seedling development. The increase in plant height observed can be attributed to increased cell wall plasticity, hydrolysis of starch into sugars (which lowers cell water potential and promotes water entry), and osmotic-driven responses influenced by gibberellins. These responses likely lead to increased photosynthetic activity, efficient translocation of nutrients, and rapid cell division in the growing parts of the plant. Chiu et al. [13] observed that proper crop establishment leads to increased plant height. This improvement is attributed to enhanced nutrient uptake, which encourages overall plant growth and promotes cell division. These results accordance with the findings of Banerjee et al. [10] and Miraj et al. [14]. Significantly higher plant height was recorded with application of treatment F2 at 60 DAS, 90 DAS and at harvest (141.96, 185.63 and 186.82 cm, respectively) as compared to treatment F1. During the initial stages, variations in plant height were not significantly affected by nitrogen levels. However, as nitrogen levels increased, plant height also increased. This growth could be attributed to enhanced cell division, cell elongation, and nucleus formation due to higher nitrogen levels. Additionally, the increased auxin supply associated with higher nitrogen levels likely contributed to greater dry matter accumulation and overall plant growth. Pal et al. [15] found that phosphorus fertilization enhances various metabolic and physiological processes, which in turn contribute to vegetative and reproductive growth through phosphorylation. These results are in conformity with the findings of Dharaiya et al. [16] and Pal et al. [15].

3.4 Days to 50% Flowering

A data presented in Table 2 revealed that days to 50% flowering were found non-significant with seed priming and fertilizer levels. However, numerically the lower days to 50 percent flowering were observed under the treatment S5 (57.5 days) and F2 (58.5 days). Effect of seed priming and fertilizer levels did not exert their significant effect on days to 50% flowering which indicates its dominance genetical inheritance characteristic of the variety.

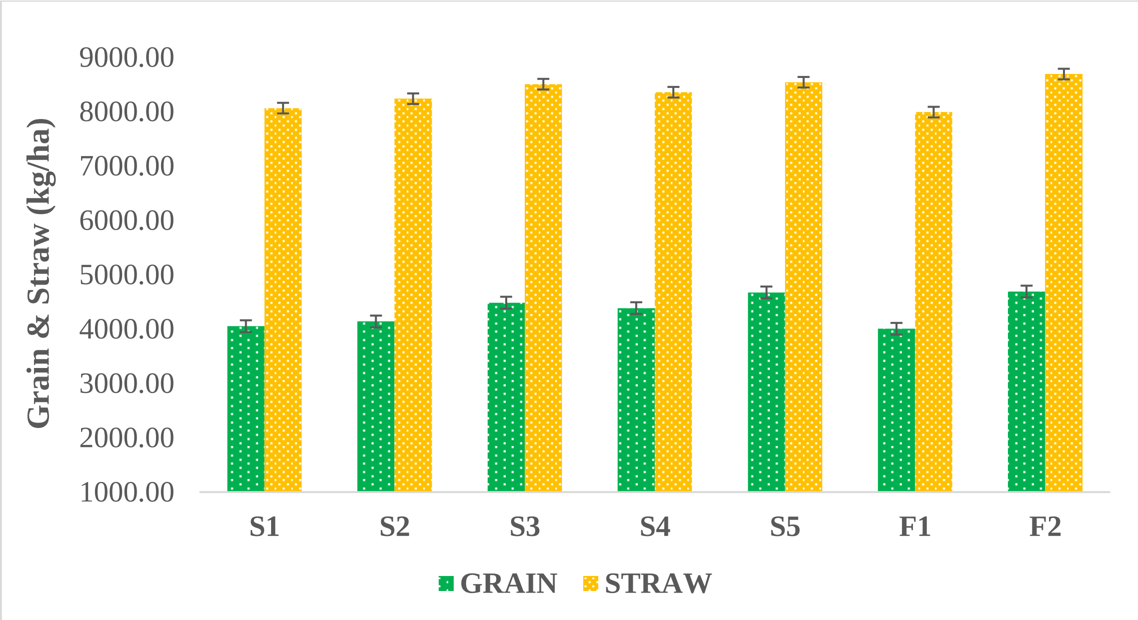

Fig. 1. Effect of various treatments on grain yield and straw yield of *rabi* maize

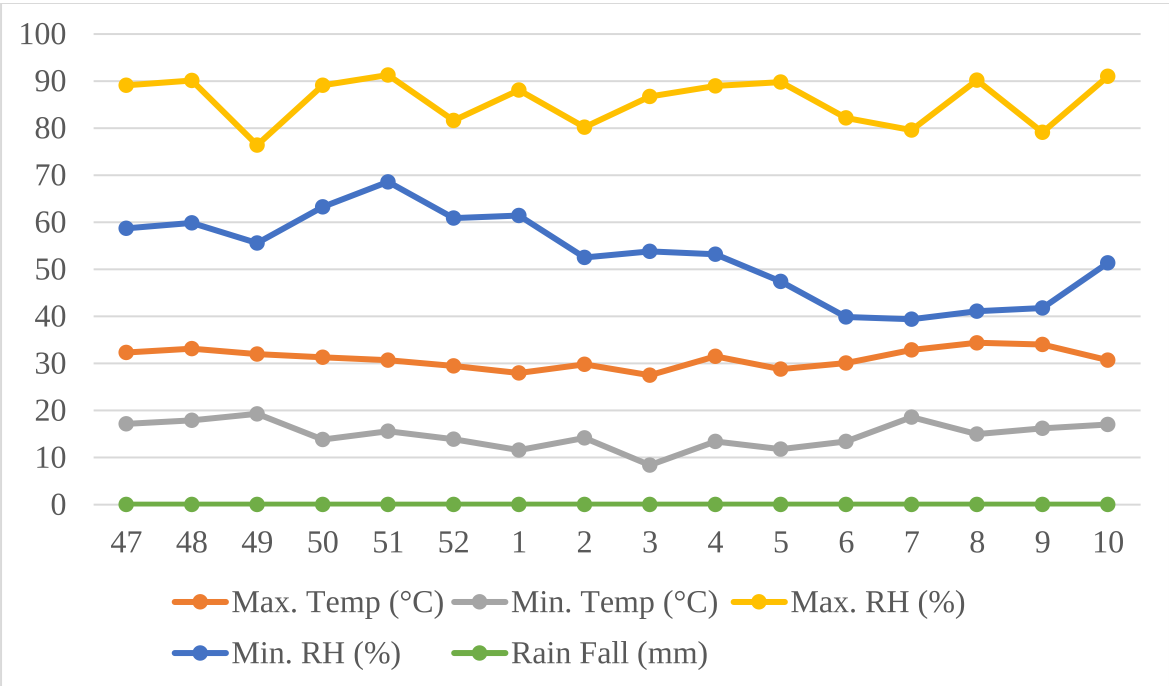

Fig. 2. Meteorological data recorded during *rabi* season of the year 2019- 20

Table 1. Influence of seed priming and fertilizer levels on Plant population, no. of leaves per plant and Plant height on *rabi* maize

Treatments	Plant population/ha		No. of leaves per plant				Plant height (cm)			
	20 DAS	at Harvest	30 DAS	60 DAS	90 DAS	at Harvest	30 DAS	60 DAS	90 DAS	at Harvest
Seed Priming (S)										
S1	76614	76590	8.07	9.6	9.67	9.58	58.63	123.97	151.63	152.28
S2	77160	77148	8.5	10.22	10.73	10.43	65.87	128.73	166.72	167.75
S3	78856	78842	8.95	11.47	11.99	11.63	71.72	136.43	179.99	181.63
S4	78378	78363	8.87	11.22	11.51	11.42	70.33	132.1	175.45	177.88
S5	79017	79007	10.13	12.82	13.07	12.63	75.27	145.43	185.15	186.9
SEm±	79.3	78.45	0.42	0.48	0.49	0.46	2	3.34	2.29	2.33
C.D. at 5%	235.59	233.00	1.24	1.43	1.46	1.36	5.92	9.92	6.87	6.92
Fertilizer Levels (F)										
F1	77931	77917	8.74	10.41	10.65	10.39	68.01	124.71	157.94	159.75
F2	78080	78064	9.07	11.72	12.14	11.89	68.71	141.96	185.63	186.82
SEm±	50.14	49.60	0.26	0.30	0.31	0.29	1.26	2.11	1.45	1.47
C.D. at 5%	NS	NS	NS	0.91	0.92	0.86	NS	6.27	4.3	4.38
S x F	NS	NS	NS	NS	NS	NS	NS	NS	S	S

Where, S1- Control, S2- Water, S3- KCl, S4- $KMnO_4$, S5- KH_2PO_4, F1- 75% RDF, F2 -100% RDF, DAS: Days after sowing; RDF: Recommended Dose of Fertilizer; NS: Non- significant

Table 2. Effect of various treatments on days to 50% flowering, cob length, cob girth, grain yield and straw yield of *rabi* maize

Treatments	Days to 50% flowering	Cob Length (cm)	Cob Girth (cm)	Grain yield (kg/ha)	Straw yield (kg/ha)
Seed Priming (S)					
S1	61.6	15.53	13.9	4054	8067
S2	59.3	16.45	14.08	4140	8240
S3	60.5	18.4	15.5	4486	8507
S4	60.6	18.71	14.75	4386	8359
S5	57.5	20.9	15.6	4675	8543
SEm±	1.51	0.66	0.36	18.87	27.83
C.D. at 5%	NS	1.96	NS	56.07	82.70
Fertilizer Levels (F)					
F1	61.3	15.91	13.05	4005	7993
F2	58.5	20.08	16.48	4691	8694
SEm±	0.95	0.42	0.36	11.93	17.60
C.D. at 5%	NS	1.24	1.07	35.46	52.30
S x F	NS	NS	NS	S	S

Where, S1- Control, S2- Water, S3- KCl, S4- $KMnO_4$, S5- KH_2PO_4, F1- 75% RDF, F2 -100% RDF, DAS: Days after sowing; RDF: Recommended Dose of Fertilizer; NS: Non- significant

Table 3. Interaction Effect of various treatments on grain yield and straw yield of *rabi* maize crop

Treatments	Grain yield (kg/ha)		Straw yield (kg/ha)	
Seed Priming (S)	Fertilizer Levels (F)			
	F1	F2	F1	F2
S1	3909	4198	7949	8186
S2	3964	4316	7993	8487
S3	4069	4904	8073	8942
S4	4015	4757	7980	8739
S5	4070	5280	7972	9114
SEm±	26.9		39.7	
C.D. at 5%	79.3		116.98	

Where, S1- Control, S2- Water, S3- KCl, S4- $KMnO_4$, S5- KH_2PO_4, F1- 75% RDF, F2 -100% RDF, RDF: Recommended Dose of Fertilizer

3.5 Cob Length cm) and Cob Girth (cm)

A data given in Table 2 showed that cob length (cm) was significantly higher with the treatment of S5 (20.9 cm) which was not found to be statistically at par with any treatment. Similar results were also observed by Priya et al. [17]. cob length (20.08 cm) and cob girth (16.48cm) was significantly higher with application of treatment F2. As nitrogen levels increased, both vegetative and reproductive growth rates in plants also increased due to an expansion of the assimilating surface area and enhanced total photosynthesis. In maize the relationship between source (photosynthesis) and sink (grain) is closely linked to nitrogen availability. These findings align with similar results reported by Ali et al. [18].

3.6 Grain Yield (kg/ha)

Data delineated in Table 2 and depicted in Fig. 1 revealed the significant variation in grain yield due to seed priming and fertilizer levels treatments. Results showed that treatment S5 (4675 kg/ha) and F2 (4691 kg/ha) considerably enhanced the grain yield as compared to other treatment. Grain yield increases due to enhanced germination rates, reduced time for seedling emergence leading to improved stand establishment, increased plant population density, augmented number of leaves per plant, consistent periodic growth in plant height, elongation of cob length, and widening of cob girth. These factors collectively facilitate the deposition of greater amounts of photo-assimilates in key plant components. Similar results were also observed by Ali et al. [19] and Miraj et al. [14]. Nitrogen (N) serves as a primary structural component of cells, with increasing nitrogen levels, both vegetative and reproductive growth rates in plants increase, attributed to the expansion of the plant's assimilating surface and overall photosynthetic capacity. Physiologically, maize grain yield is predominantly influenced by the interplay between source (photosynthesis) and sink (grain) dynamics, directly linked to nitrogen levels. Elevated nitrogen content correlates with higher grain yields. Adequate nitrogen availability throughout the growth period proves vital for various plant processes, including chlorophyll production, enzyme synthesis, and facilitation of potassium and phosphorus utilization. Similar results were also observed by Ali et al. [18].

3.7 Straw Yield (kg/ha)

Data delineated in Table 2 and depicted in Fig. 1 revealed the significant difference in straw yield due to seed priming and fertilizer levels. Results showed that treatment S5 (8543 kg/ha) and F2 (8694 kg/ha) considerably enhanced the straw yield which was found to be statistically at par with treatment S3 (8507 kg/ha). Whereas, significantly lowest straw yield was recorded with control treatment (no priming) (8067 kg/ha.). Straw yield increases due to improves germination, reduces seedling emergence time improves stand establishment, higher plant population, no. of leaves per plant, periodically plant height, which encouraged deposition of more photo-assimilates in key plant parts. Similar results were also observed by Ali et al. [19] and Miraj et al. [14]. Sufficient fertilizer dose favourable for vegetative growth and root development as they received adequate and sufficient nitrogen and phosphorus in proper amount at critical stage. As the results, the plant height and yield attributing characters improved through increased photosynthetic activity of leaves. Similar results were also observed by Ali et al. [19] and Miraj et al. [14].

3.8 Interaction Effect

The data in Table 3 showed that interaction effect of seed priming and fertilizer levels was found significant for grain and straw yield. Grain and straw yield was significantly higher recorded with treatment combination S5F2 (5280 kg/ha and 9114 kg/ha, respectively). Ali et al*.* [19] confirmed that seed soaking with a 1% phosphorous solution using KH_2PO_4 improved fertilizer use efficiency while increasing yield and profit for several crops. Similar results were also observed by Patil et al*.* [20].

4. CONCLUSION

On the basis of one year experimentation, it can be concluded that *rabi* maize should be seed primed with KH_2PO_4 at 0.5 % for 12 hrs along with application of 100 % RDF (150+60+00 N: P_2O_5: K_2O kg/ha) and 5 t/ha Bio-compost for obtaining higher Plant population, no. of leaves per plant, plant height, seed and straw yield under south Gujrat condition.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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