Impact of Seed Priming and Fertilizer Levels on quality, yield and economics of *Rabi* Maize

ABSTRACT

The present investigation was conducted during the *rabi* season of 2019-20 at College of Agriculture, NAU, 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 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 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 grain yield (46.75 q/ha), straw yield (85.43 q/ha), harvest index (35.23%), protein yield (567.20 kg/ha), net return (₹ 74618/ha) and B:C ratio (2.24) as compared to other treatments. In case of fertilizer levels recorded significantly higher grain yield (46.91 q/ha), straw yield (86.94 q/ha), harvest index (34.99%), protein content (12.41 %), protein yield (584.23 kg/ha), net return (₹74742/ha) and B:C ratio (2.33) in treatment of 100% RDF (150+60+00, N: P_2O_5: K_2O kg/ha). Treatment combination S_5F_2 (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 grain yield (52.80q/ha), straw yield (91.14 q/ha), harvest index (36.68%), Protein yield (686.56 kg/ha) net return (₹86657/ha) and B:C ratio (2.56) 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 increasing grain yield, straw yield, harvest index, protein yield, net return and B:C ratio of *rabi* maize without negative influence on plant and the environment.

Keyword: *Seed priming, fertilizer, yield, protein, B:C ratio, maize*

1. INTRODUCTION

Maize (Zea mays L.) is a significant cereal crop worldwide, following wheat and rice. Its importance extends beyond serving as human food and animal feed, as it finds wide industrial applications. Maize stands out as a versatile crop, adapting well to diverse agro-ecologies, and boasting the highest yield potential among food grain crops (Choudhary *et al.,* 2024). With global demand increasing due to its multifaceted uses in food, feed, and industry, we must enhance production efficiency using existing or fewer resources. New agricultural technologies hold great promise for meeting the growing needs of consumers worldwide. Known as the 'queen of cereals,' maize is cultivated year-round due to its photo-thermosensitive nature. While predominantly a kharif season crop, rabi maize has gained significant prominence in India's overall maize production in recent years.

Several factors influence the productivity of *rabi* maize, with fertilizer management being a critical determinant of growth and yield. Maize, an exhaustive crop, requires a comprehensive range of macro and micronutrients to achieve optimal growth and exploit its yield potential. Notably, nitrogen utilization efficiency is higher during the *rabi* season compared to the *kharif* season, primarily due to improved water management and reduced leaching losses, resulting in better fertilizer response. Consequently, substantial cost reductions in maize production during the *rabi* season are feasible. The specific quantity of fertilizers needed depends on soil fertility and prior field management. Among the essential plant nutrients, nitrogen, phosphorus, and potassium play pivotal roles in shaping growth and yield. Nitrogen is essential for increasing crop production, serving as a constituent of protoplasm and chlorophyll. It plays a crucial role in the activity of every living cell. Similarly, phosphorus contributes to energy storage and transfer within the plant system. Additionally, phosphorus is a vital component of nucleic acids, phytins, phospholipids, and enzymes. Numerous studies have highlighted the positive impact of NPK fertilization on maize productivity (Mehta *et al.*, 2005; Rajanna *et al.*, 2006; Makwana *et al.*, 2016)

Germination and seedling emergence represent critical stages in the plant life cycle. Inadequate seedling emergence and improper stand establishment pose significant challenges in crop production, especially in regions with limited rainfall. Small-scale farmers often lack the necessary resources for proper seedbed preparation, putting them at greater risk compared to their more progressive counterparts. Conversely, successful establishment enhances competitiveness against weeds, improves drought tolerance, increases yield, and eliminates the time-consuming need for costly re-sowing. It is widely accepted that priming enhances germination, reduces seedling emergence time, and promotes robust stand establishment. A technique to enhance germination rate and uniformity involves seed priming or the physiological advancement of seed lots. Seed priming is a pre-sowing treatment where seeds are soaked in water and then dried back to storage moisture levels before planting. This method helps crop plants with stand stress factors like drought and pest damage, ultimately leading to increased crop yield (Harris *et al.*, 1999). 'Nutrient seed priming' is a technique where seeds are soaked in a nutrient solution instead of pure water. This approach aims to increase seed nutrient content while also improving seed quality for better germination and seedling establishment. The primary purpose of seed priming is to partially hydrate the seeds, initiating germination processes. When re-imbibed under normal or stress conditions, these primed seeds exhibit rapid germination. This simple and cost-effective hydration technique involves partially hydrating the seeds to the point where pre-germination metabolic activities begin without actual germination. The seeds are then re-dried until they reach a weight close to their original dry weight (Casenave and Tosselli, 2007). The purpose of this research is to investigate and assess the impact of seed priming techniques and varying levels of fertilization on the quality, yield, and economic aspects of *rabi* maize cultivation. By conducting this study, we aim to determine the optimal combination of seed priming methods and fertilizer levels that can enhance maize quality, increase yield productivity, and improve economic outcomes for farmers during the *rabi* season.

MATERIALS AND METHOD

2.1 Description of experiment site

The field experiment was conducted at B-block of Agronomy Farm, N. M. College of Agriculture, Navsari Agricultural University (NAU), Navsari during *rabi* season of 2019-20. Navsari Agriculture University campus is situated at 20°57' N latitude and 72°54' E longitude, with an altitude of 10 meters above sea level. The climate in this region features hot summers, moderately cold winters, and a warm humid monsoon season with heavy rainfall. Winter typically begins in the first week of November and extends until mid-February. The soil of the experimental plot exhibits an alkaline reaction, with dry soil appearing dark brown and having a clayey texture.

2.2 Treatments and Experimental Design

Total ten treatment combinations of two factors were evaluated as under 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: K2O kg/ha). Common application of

Bio compost 5 t/ha in every treatment combination. The experiment followed a Randomized Block Design (Factorial concept) with three replications, featuring plots of 6.0 m ×5.0 m each.

2.3 Experimental procedures and field management

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. Seeds of *rabi* maize were soaked in a prepared solution containing various chemicals separately for 12 hours. After soaking, the seeds were dried in the shade until the seed coat became dry (Sharma and Parmar, 2018). The total quantity of phosphorus and half the quantity of nitrogen were applied as a basal dose, while the remaining half of the nitrogen was given as a split application three weeks after sowing. The nutrients were applied in the form of urea (46% N) and single superphosphate (16% P_2O_5), with a dose of 150+60+00 N: P_2O_5: K_2O kg/ha using the band placement method and varying doses according to the treatment.

The field was prepared using a tractor-drawn M.B. plough and planking, following the layout plan. For sowing, the recommended seed rate of 20 kg/ha was used. Seed quantities were measured for each plot, and various priming techniques were applied according to the treatment before manual sowing at a depth of 4-5 cm using line sowing. The crops received irrigation five times. After sowing, the first irrigation was provided to ensure proper germination. For effective weed control, manual weeding was performed at 30 days after sowing (DAS), along with inter cultivation using a mechanical weeder. Overall, the crop stand was satisfactory, and there were no instances of pest or disease attacks. As a preventive measure against maize stem borers, Carbofuran 3G was applied at a rate of 15 kg/ha at 20 DAS

2.4 Data Collected and collecting Procedure

Cobs from all the plants in each net plot were individually harvested and sun-dried for approximately 10 days. Once the cobs were completely dry, the grains were separated using wooden sticks. The resulting produce was then cleaned and weighed. To determine the total grain weight per plot, we summed the grain weight of five sample plants and converted it to a hectare basis. Additionally, after harvesting the cobs, the plants themselves were harvested separately from the net plot and allowed to sun-dry in the field for a similar duration. These dried plants were then bundled appropriately, and the 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 converting it to a hectare basis. Finally, the harvest index was calculated using the following formula (Donald and Hamblin, 1976).

$$\text{Harvest index (\%)} = \frac{\text{Economical yield (kg/ha)}}{\text{Biological yield (kg/ha)}} \times 100$$

Protein content of seed was determined by multiplying nitrogen percentage with 6.25. Protein yield was computed by using following formulae:

$$\text{Protein yield (kg/ha)} = \frac{\text{Protein content(\%)}xDrymatteryield(kg/ha)}{100}$$

The expenses incurred for all cultivation operations, from preparatory tillage to threshing, including the costs of inputs such as seeds and fertilizers, were calculated based on prevailing market prices. Gross realization was determined using grain and straw yield per hectare for each treatment, considering market rates. The overall cost of cultivation accounted for land preparation, crop harvesting, and all associated inputs. Net realization per hectare was calculated by subtracting the total cultivation cost from the gross realization. The benefit-cost ratio (B:C ratio) was computed using the following formula.

$$\text{B: C Ratio} = \frac{\text{NET RETURN}}{\text{COST OF CULTIVATION}}$$

2.5 STATISTICAL ANALYSIS

Statistical analysis of the data on maize yield, quality, and economic aspects during the investigation followed the variance analysis technique described by Panse and Sukhatme (1985). The method employed for the Factorial Randomized Block design involved an analysis of variance, and treatment effects on all the studied characters were further compared using the ‘F’ test (Gomez and Gomez, 1984). A significance level of five percent was used to assess the results, and the critical difference (CD at 5%) value was calculated for treatments with significant differences.

3 RESULTS AND DISSCUTION

3.1 Grain Yield (q/ha)

Data delineated in table 1 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 (46.75 q/ha) and F2 (46.91 q/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.* (2016a) and Miraj *et al.* (2013). 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 primarily influenced by the interaction between source (photosynthesis) and sink (grain) dynamics, which is directly associated with 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.* (2016).

3.2 Straw Yield (q/ha)

Data table 1 and depicted in fig. 1 revealed the significant difference in straw yield due to seed priming and fertilizer levels. Results delineated in showed that treatment S5 (85.43 q/ha) and F2 (86.94 q/ha) considerably enhanced the straw yield which was found to be statistically at par with treatment S3 (85.07 q/ha). Whereas, significantly lowest straw yield was recorded with control treatment (no priming) (80.67 q/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.* (2016) and Miraj *et al.* (2013). 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.* (2016) and Miraj *et al.* (2013).

3.3 Harvest Index (%)

Data delineated in table 1 and depicted in Fig. 1 revealed the significant variation in harvest index due to seed priming and fertilizer treatments. Results showed that seed priming of maize by treatment S5(35.23%) and fertilizer level treatment F2 (34.99 %)considerably higher harvest index. which was not found to be statistically at par with any treatment. Whereas, significantly lowest harvest index was recorded with control treatment (no priming) (33.43 %). higher harvest index due to higher grain and straw yield with treatment KH_2PO_4. Similar results were also observed by Ali *et al*. (2016).

3.4 Protein Content (%)

A data presented in table 1 revealed that protein content (%) was found non-significant with seed priming. However, numerically higher protein content (12 %) was observed under the treatment S5and lower protein content (11.27 %) was noted in treatment S1.The present findings are very similar with the findings of Singh *et al*. (2016). Protein content (%) was significantly higher (12.41 %) with application of treatment F2 as compared with treatment F1. Pal *et.al* (2017) found thateach increase in fertilizer level linearly increased grain protein content. Due to N, it is a major constituent of proteins. The significant improvement in the phosphorus (P) nutrient status of plant parts (stover) may have led to increased synthesis of amino acids, proteins, and growth-promoting substances.

3.5 Protein yield (kg/ha)

A data given in table 1 revealed that protein yield (kg/ha) was significantly higher with the fertilizer level F2 (584.23 kg/ha) and seed priming S5 (567.20 kg/ha) which was found to be statistically at par with treatment S3 (532.54 kg/ha).The higher protein yield can be attributed to increased nitrogen uptake. Nitrogen is a major constituent of amino acids, which are the building blocks of proteins. Additionally, nitrogen is part of DNA, RNA, and nucleic acids. The increased availability of nitrogen and its storage in the grain likely contributed to this effect. Since nitrogen is the principal component of proteins, the higher protein content in the kernel may be due to increased nitrogen uptake. The elevated fertilizer levels could also be linked to greater cellular protoplasm and increased protein yield. These findings align with previous studies by Singh *et al.*, (2016) and Khan *et al.*, (2018) in maize crops

3.6 Interaction Effect

The data in table 3 revealed a significant interaction effect between seed priming and fertilizer levels on grain yield, straw yield, harvest index, and protein yield. Among the treatment combinations, S5F2 (52.80 q/ha grain yield, 91.14 q/ha straw yield, 36.68% harvest index, and 686.56 kg/ha protein yield) exhibited significantly higher values. Notably, Ali *et al.,* (2016) found that seed soaking with a 1% phosphorus solution (using KH_2PO_4) improved fertilizer use efficiency and increased yield and profit across various crops. These findings align with similar results reported by Patil *et al.,* (2018).

3.7 Effect on Economics

In table 1, the data on the economics of *rabi* maize influenced by different seed priming and fertilizer levels are presented. The results indicate that the highest gross returns (₹107848/ha), net returns (₹74618/ha), and benefit-cost ratio (BCR) of 2.24 were achieved with seed priming treatment S5, followed by treatment S3. Similarly, the highest gross returns (₹108525/ha), net returns (₹74742/ha), and BCR of 2.21 were observed with fertilizer level treatment F2. Conversely, the lowest gross returns (₹94093/ha), net returns (₹61465/ha), and BCR of 1.88 were associated with treatment F1. These variations may be attributed to increased fertilizer levels, improved yield attributes, higher grain and straw yields. (Raskar *et al.,* 2016; Thakur *et al.,* 2016)

3.8 Interaction effect on economics

Data presented in table 3 revealed that higher gross returns ₹ 120465/ha, net returns ₹ 86657/ha and benefit: cost ratio (BCR) 2.56 obtained with treatment combination of S5F2 followed by treatment combination of S3F2 which secured ₹ 113080/ha gross returns, ₹ 79087 net returns and 2.33 benefit: cost ratio (BCR). However, the lowest gross returns ₹ 92201/ha net returns ₹ 59801/ha and benefit: cost ratio (BCR) 1.85 was noted with treatment combination of S1F1. It might be due to higher dose of nitrogen triggered the vigorous growth of plant and less competition for the nutrient (Thakur *et al.* 2016).

CONCLUSION

On the basis of one year experimentation, it can be concluded that *rabi* maize 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 grain yield, straw yield, protein content, protein yield and net return under south Gujarat condition.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

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

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Table 1.Effect of various treatments on grain yield, straw yield, harvest index, protein content, protein yieldand economics of *rabi* maize

Treatments	**Grain yield (q/ha)**	**Straw yield (q/ha)**	**HI (%)**	**Protein (%)**	**Protein yield (kg/ha)**	**Cost of cultivation (₹/ha)**	**Gross returns(₹/ha)**	**Net returns(₹/ha)**	**B:C ratio**
					Seed Priming (S)				
S1	40.54	80.67	33.43	11.27	457.13	32977	95170	62193	1.89
S2	41.40	82.40	33.43	11.6	481.20	33155	97204	64048	1.93
S3	44.86	85.07	34.46	11.8	532.54	33415	104276	70860	2.12
S4	43.86	83.59	34.36	11.75	518.48	33250	102049	68799	2.07
S5	46.75	85.43	35.23	12	567.20	33230	107848	74618	2.24
SEm±	**0.18**	**0.27**	**0.092**	**0.24**	**12.54**		**383.15**	**383.15**	**0.011**
C.D. at 5%	**0.56**	**0.82**	**0.52**	**NS**	**37.27**		**1138.4**	**1138.4**	**0.034**
					Fertilizer Levels (F)				
F1	4005	7993	33.38	10.94	438.38	32628	94093	61465	1.88
F2	4691	8694	34.99	12.41	584.23	33783	108525	74742	2.21
SEm±	**0.11**	**0.17**	**0.058**	**0.15**	**7.93**		**242.32**	**242.32**	**0.007**
C.D. at 5%	**0.35**	**0.52**	**0.174**	**0.46**	**23.57**		**720**	**720**	**0.021**
S x F	**S**	**S**	**S**	**NS**	**S**		**S**	**S**	**S**

Where, HI- Harvest index, S1- Control,S2- Water, S3- KCl, S4- $KMnO_4$, S5-KH_2PO_4,F1- 75% RDF, F2 -100% RDF, RDF: Recommended Dose of Fertilizer, B:C ratio – Benefit cost ratio, ₹- Indian rupee.

Table 2. Interaction Effect of various treatments on grain yield and straw yield of *rabi* maize crop

Treatments	**Grain yield (q/ha)**		**Straw yield (q/ha)**		**Harvest index (%)**		**Protein yield (kg/ha)**	
Seed Priming (S)	**Fertilizer Levels (F)**							
	F1	**F2**	**F1**	**F2**	**F1**	**F2**	**F1**	**F2**
S1	39.09	41.98	79.49	81.86	32.97	33.90	424.37	489.88
S2	39.64	43.16	79.93	84.87	33.15	33.71	431.9	530.50
S3	40.69	49.04	80.73	89.42	33.52	35.42	447.66	617.43
S4	40.15	47.57	79.80	87.39	33.47	35.25	440.15	596.80
S5	40.70	52..80	79.72	91.14	33.80	36.68	447.83	686.56
SEm±	**0.26**		**0.39**		**0.13**		**17.74**	
C.D. at 5%	**0.79**		**1.16**		**0.39**		**52.71**	

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.

Table-3. Effect of various treatments combinations on yield and economics of maize crop

Treatment	**Yield (q/ha)**		**Cost of cultivation (₹/ha)**	**Gross returns (₹/ha)**	**Net returns (₹/ha)**	**B:C ratio**
	Grain	**Straw**				
S_1F_1	39.09	79.49	32400	92201	59801	1.85
S_1F_2	41.98	81.86	33555	98140	64585	1.92
S_2F_1	39.64	79.93	32578	93330	60752	1.86
S_2F_2	43.16	84.87	33733	101077	67344	2.00
S_3F_1	40.69	80.73	32838	95471	62633	1.91
S_3F_2	49.04	89.42	33993	113080	79087	2.33
S_4F_1	40.15	79.80	32673	94234	61561	1.88
S_4F_2	47.57	87.39	33828	109865	76037	2.25
S_5F_1	40.70	79.72	32653	95232	62579	1.92
S_5F_2	52.80	91.14	33808	120465	86657	2.56
SEm±	**0.26**	**0.39**				
C.D. at 5%	**0.79**	**1.16**				

Where, S - Seed priming, F- Fertilizer level, S1- Control,S2- Water, S3- KCl, S4- $KMnO_4$, S5-KH_2PO_4,F1- 75% RDF, F2 -100% RDF,B:C ratio – Benefit cost ratio, ₹- Indian rupee.

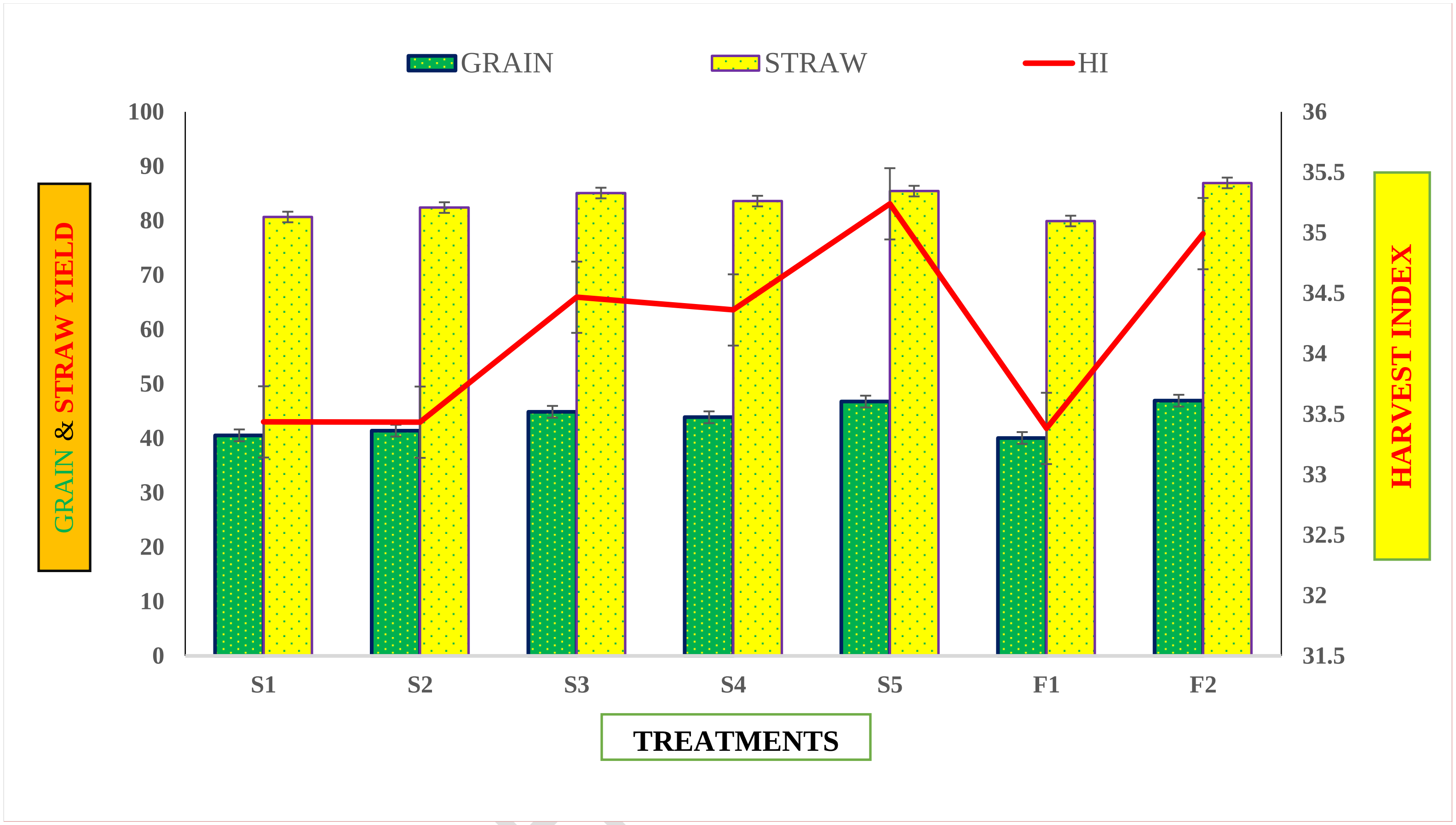

Fig 1. Effect of various treatments on grain yield, straw yield and harvest index of maize