Indian Journal of Ecology (2024) 51(5): 985-996
DOI: https://doi.org/10.55362/IJE/2024/4340

Manuscript Number: 4340
NAAS Rating: 5.38

Grain Quality, Soil Fertility Status and Nutrient Uptake Pattern of Emmer Wheat (*Triticum dicoccum* L.) under System of Wheat Intensification

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***Abstract*:** Maintaining sustainable soil fertility level and enhancing emmer wheat production on smallholder farms is a great challenge in the Northern Dry Zone of Karnataka. Therefore, the present investigation on the grain quality, soil fertility status and nutrient uptake pattern of emmer wheat (*Triticum dicoccum* L.) under System of Wheat Intensification (SWI) in irrigated ecosystem conditions. Field experiment was conducted during *rabi* season of 2022-23 at Research field of Ugar Khurd, Belagavi, Karnataka. The experiment was laid out in a split plot design with four main plots *viz.,* Gokak local and DDK 1029 with and without seed priming and four planting geometries *viz.,* 30 × 15 cm; 45 × 15 cm; 20 × 20 cm and 20 cm (RPP) in sub plots under three replications. The primed seeds sown at 30 × 15 cm planting geometry recoded significantly higher number of effective tillers (463.83 m^{-2}), grain yield (44.13 q ha^{-1}), straw yield (70.64 q ha^{-1}), biological yield (114.77 q ha^{-1}), grain protein content (12.54 %), nitrogen, phosphorous and potassium content (2.65, 0.54 and 1.78 %) and total nitrogen, phosphorous and potassium uptake (133.63, 28.38 and 112.44 kg ha^{-1}) as compared to un-primed seeds with other planting geometries.

***Keywords*:** Emmer wheat, Nutrient contents and uptakes, Planting geometries, Seed priming, System of wheat intensification

Wheat is grown across a wide range of environmental conditions around the world. Cultivation of wheat dates back to more than 5000 years, during the period of Indus valley civilization during which the original species *Triticum sphaerococcum*, traditionally known as Indian wheat has vanished and replaced by modern day cultivars like *Triticum aestivum* (Bread wheat), *Triticum durum* (Macaroni wheat or Kathia wheat) and *Triticum dicoccum* (Emmer wheat or Khapli). Among different species of wheat, *Triticum aestivum* has 95 per cent production, *Triticum durum* has 4 per cent and *Triticum dicoccum* has one per cent production in India. Nearly, 82 to 85 per cent of the wheat grown in India is under irrigated situation, while the rest is grown under rainfed condition. The emmer wheat (*Triticum dicoccum* L.) is grown on a very restricted scale in Gujarat, Maharashtra and Karnataka. In general emmer wheat varieties are rich source of protein and complex carbohydrate (dietary fibre) as compared to bread wheat and it keeps one full for longer and hence helps in weight loss. The traditional products of emmer wheat varieties have better taste, texture and flavour (Singh, 2015).In India, wheat cultivation covers an extensive 30.47 million hectares and contributes significantly to food grain production, accounting for 36 per cent of the total output (Anonymous 2022). Lower wheat productivity is primarily due to delayed sowing, a short winter season, improper input management and terminal heat stress, particularly in the North Eastern Plain Zone of India, which leads to reduced tillering, inadequate crop establishment and shrivelled grains and yields. Traditionally, wheat cultivation has relied on the broadcasting and continuous sowing of seeds in rows without adhering to specific planting geometry. This approach has served well for extensive agricultural areas. However, it comes with limitations, such as the lack of uniformity in crop stand. This lack of uniformity results in the dilution effect of inputs and impacting on crop yield (Haque et al 2015). The System of Wheat Intensification (SWI) represents an innovative approach to wheat production on manipulating the soil environment with minimal external inputs and utilizing a very low seed rate. This technique aims to create optimal conditions for wheat cultivation, emphasizing the importance of maintaining an ideal plant population, SWI ensures adequate aeration, moisture, sunlight, and nutrient availability, which are crucial for fostering proper root system development during the early stages of crop growth. This holistic approach to wheat farming holds promise for improving yields and resource utilization while reducing external inputs.

The System of Wheat Intensification method was initially introduced in India, Africa, and Nepal by dedicated community workers on the fields of small and marginal farmers in the year 2006. These grassroots efforts yielded encouraging results, which played a pivotal role in inspiring and guiding systematic research initiatives involving farmers, government agencies and research workers in India. SWI, a synergistic wheat farming technique, involves reduced seed density and wider spacing, coupled with seed treatment using organic formulations like cow dung, cow urine, jaggery and curd, to enhance plant health and productivity. Under the SWI the management practices create more favourable conditions for wheat crop growth. This is achieved through the greater proliferation of root hair and increased root length compared to traditional wheat farming methods, (Haque *et al* 2015). Despite encouraging results, there is limited information available regarding the overall effect of the SWI technique on wheat growth and productivity. Further research and data collection in this area could provide valuable insights into the full potential and benefits of adopting SWI in wheat farming. Therefore, the present experiment was conducted to investigate the "Grain quality, soil fertility status and nutrient uptake pattern of emmer wheat (*Triticum dicoccum* L.) under System of Wheat Intensification (SWI).

MATERIAL AND METHODS

Experiment site: The present investigation was conducted at Research field of Ugar Khurd, Belagavi, Karnataka, during *rabi* 2022-2023 located in the Northern Dry Zone (Zone-3) of Karnataka. Geographically it lies between 16º 38' 30" N latitude, 74º 49' 39" E longitude and at an altitude of 561 m above mean sea level (MSL).

Soil status: Experiments were laid out on well drained, deep black calcareous soil taxonomically belonging to vertisol with a depth of 2.5 to 3.5 m and slightly saline in nature with pH of pH ranging from 8.0 with medium electrical conductivity (0.39 dS m^{-1}), low in organic carbon content (0.58 %), low in available nitrogen (279.1 kg ha^{-1}), high in available phosphorous (32.6 kg ha^{-1}) and potassium (371.2 kg ha^{-1}).

Treatment details: The experiment was laid out in split plot design with four main plots *viz.,*gokak local and DDK 1029 with and without seed priming and four planting geometries in sub plots *viz.,* S_1- 30 × 15 cm; S_2- 45 × 15 cm; S_3- 20 × 20 cm and S_4- 20 cm (RPP). The seed rate varies with respective planting geometries and crop was sown during 1st week of November and harvest during 2nd week of March.

Seed priming procedure: Seed priming formulation comprising of water, cow dung, cow urine, jaggery and curd in the ratio of 2.0: 0.5: 0.5: 0.1: 0.05 was used to treat the seeds before sowing. In this case for priming 10 kg of emmer wheat seed, 10 litres of water, 2.5 kg of cow dung, 2.5 litre of cow urine, 500 g of jaggery and 250 g curd was taken in a bucket and was kept overnight (Sunaratiya and Banik 2022). The priming material was stirred during preparation period. Thereafter, the material was sieved using cotton cloth and the resultant solution so obtained was used as priming formulation to treat the seeds. The seeds of wheat to be treated were first immersed in water contained in the tub to remove the chaffy seeds which were found floating on the surface of water. The seeds which settled in the bottom of the tub were collected and immersed in the priming solution for eight to ten hours. Took the seeds out of the priming solution and dried in shade. Thereafter were sown directly in the field.

Quality parameters analysis: i) Protein, nitrogen is determined by a method of chemical analysis known as the Kjeldahl procedure. Crude protein content was calculated by following formula: Crude protein of wheat = Per cent nitrogen × 5.7. ii) Grain N content was determined by Kjeldahl method described by (Kjeldahl, 1883) and expressed in percentage. iii) Grain P Content Total phosphorous on dry weight basis at harvest of wheat was estimated by Vanadomolybdo-phosphoric acid yellow colour method and expressed in percentage. iv) Grain K Content Available potassium in grain was extracted with neutral normal ammonium acetate and potassium content in the extract will be determined by using flame photometer (EelicoD-22) as outlined by (Jackson, 1973) and expressed in percentage.

Nutrient uptake by wheat: The uptake of nutrients by different parts of wheat was worked out by multiplying the nutrient content in seed and straw yield of the plant using the following formula:

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient concentration in grain (\%)} \times \text{Grain yield (kg ha}^{-1}\text{)}}{100} + \frac{\text{Nutrient concentration in Straw (\%)} \times \text{Straw yield (kg ha}^{-1}\text{)}}{100}$$

Soil sample analysis: Soil samples were collected before sowing and after harvest from individual plots of experiment by taking slice of soil from the depth of 0-30 cm. Soil samples were shade dried, powdered using wooden pestle and mortar and sieved through 2 mm sieve and chemically analysed to estimate soil reaction (pH), EC (dS m^{-1}), organic carbon (OC %), available soil nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O).

Statistical analysis and interpretation of data: The data were analysed in MS EXCEL (var. 2020) by using DMRT.

RESULTS AND DISCUSSION

Yield and yield attributes of emmer wheat as influence by seed priming

Number of effective tillers (m^{-2}): Seed priming significantly influenced the number of effective tillers of emmer wheat. Primed seeds (M_4) recorded significantly higher number of effective tillers (422.14 m^{-2}) and was on par with M_2 and M_3. However, significantly lowest number of effective tillers (401.86 m^{-2}) was in un-primed seeds (M_1) (Table 1). This can be due to fact that cow urine contains physiologically active substances *viz.,* growth regulators and nutrients that promote profusely more number of tiller per plant. Bhoopathi et al (2001) also observed significant increase number of tillers per plant due to treating of seed with cattle urine than untreated seed.

Grain yield (q ha^{-1}): Grain yield differed significantly with respect to with and without seed priming. Primed seeds (M_4) recorded significantly higher grain yield (38. 53 q ha^{-1}) and was on par with M_2 and M_3. The, significantly lower grain yield (32.78 q ha^{-1}) was in un-primed seeds) (Table 1). Seed priming also imparted a positive influence on grain and straw yield of wheat as compared to un-primed seed. The increase in grain yield of wheat under seed priming might be due to its positive effect on growth and yield parameters *viz.,* crop emergence, complete crop emergence, both above and belowground plant growth and yield attributes over un-primed seeds. Khadka and Raut (2011) and Sarlach et al (2013) have also reported that seed priming improves emergence, stand establishment, tillering, grain and straw yields.

Straw yield (q ha^{-1}): Primed seeds (M_4) recorded significantly higher straw yield (64.26 q ha^{-1}). Whereas, significantly lower straw yield (58.88 q ha^{-1}) was recorded with respect to un-primed seeds (M_1) (Table 1). The higher

Table 1. Yield and yield attributes of emmer wheat as influenced by seed priming and different planting geometries

Treatment	Number of effective tillers m^{-2}	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Biological yield (q ha^{-1})
Main plots:- (Two genotypes with and without seed priming)				
M_1-Gokak local (WOP)	401.86^{b}	32.78^{b}	58.88^{b}	91.65^{b}
M_2- Gokak local (WP)	412.88^{ab}	36.15^{ab}	61.09^{b}	97.24^{ab}
M_3-DDK 1029 (WOP)	409.51^{ab}	35.01^{ab}	61.42^{b}	96.43^{b}
M_4-DDK 1029 (WP)	422.14^{a}	38.53^{a}	64.26^{a}	102.79^{a}
Sub plots:- (Four planting geometries)				
S_1- 30 × 15 cm	452.85^{a}	40.20^{a}	66.30^{a}	106.50^{a}
S_2- 45 × 15 cm	357.61^{d}	34.08^{b}	60.06^{bc}	94.14^{bc}
S_3- 20 × 20 cm	433.58^{b}	36.74^{ab}	61.78^{b}	98.51^{ab}
S_4- 20 cm (RPP)	402.34^{c}	31.45^{c}	57.52^{c}	88.96^{c}
Interaction (M × S)				
M_1S_1	439.73^{bc}	36.31^{a-d}	63.01^{cd}	99.32^{cd}
M_1S_2	347.77^{g}	31.52^{cd}	57.93^{f}	89.45^{e-g}
M_1S_3	424.83^{cd}	34.06^{b-d}	59.88^{ef}	93.94^{d-f}
M_1S_4	395.10^{e}	29.21^{d}	54.68^{g}	83.89^{g}
M_2S_1	460.17^{a}	42.35^{ab}	65.99^{b}	108.34^{ab}
M_2S_2	356.87^{g}	34.13^{b-d}	59.20^{ef}	93.33^{d-g}
M_2S_3	434.70^{bc}	37.02^{a-d}	61.66^{de}	98.67^{c-e}
M_2S_4	399.77^{e}	31.11^{cd}	57.52^{fg}	88.64^{fg}
M_3S_1	447.68^{ab}	38.01^{a-c}	65.55^{bc}	103.56^{bc}
M_3S_2	350.77^{g}	35.00^{b-d}	60.16^{ef}	95.16^{c-f}
M_3S_3	434.87^{bc}	35.47^{b-d}	61.89^{de}	97.36^{c-f}
M_3S_4	404.73^{e}	31.56^{cd}	58.07^{f}	89.62^{e-g}
M_4S_1	463.83^{a}	44.13^{a}	70.64^{a}	114.77^{a}
M_4S_2	375.03^{f}	35.68^{b-d}	62.94^{cd}	98.62^{c-e}
M_4S_3	439.93^{bc}	40.40^{ab}	63.68^{b-d}	104.08^{bc}
M_4S_4	409.77^{de}	33.90^{b-d}	59.80^{ef}	93.70^{d-f}

Mean followed by the same letter(s) did not differ significantly by DMRT (p= 0.05)

straw yield in primed seeds compared to un-primed seeds can be attributed to increased seedling vigour, stronger vegetative growth, greater dry matter production and improved growth parameters. This collective effect results in enhanced straw biomass, making seed priming with organic formulations a valuable method for boosting wheat straw yield. Similar results were also obtained by Khadka and Raut (2011) and Sarlach et al (2013).

Biological yield (q ha^{-1}): Primed seeds (M_4) recorded significantly higher biological yield (102.79 q ha^{-1}) and it was recorded on par with M_2 (97.24 q ha^{-1}). The significantly lowest biological yield (91.65 q ha^{-1}) was recorded with respect to un-primed seeds (M_1) (Table 1). The increase in grain and straw yields in primed seeds as compared to un-primed seeds can be attributed to improved seedling vigour, early growth and enhanced vegetative development. Seed priming proves effective in boosting overall crop performance, leading to higher yields in both grain and straw in wheat cultivation. Similar results were also obtained by Sharma (2020).

Quality Parameters of Emmer Wheat as Influenced by Seed Priming

Grain crude protein content of emmer wheat: Significant differences in grain crude protein content were observed with respect to with and without seed priming methods. Primed seeds (M_4 and M_2) recorded significantly higher grain crude protein content (12.05 and 11.96 %, respectively). The significantly lowest grain crude protein content (11.08 %) was with respect to un-primed seeds (M_1) (Table 2). These might be due to higher grain nitrogen content in primed seeds and

Table 2. Grain crude protein and nitrogen content of emmer wheat as influenced by seed priming and different planting geometries

Treatment	Grain crude protein content (%)	Nitrogen content in (%)		
		Grain	Straw	Total
Main plots:- (Two genotypes with and without seed priming)				
M_1-Gokak local (WOP)	11.08^{c}	1.62^{b}	0.48^{b}	2.09^{b}
M_2- Gokak local (WP)	11.96^{a}	1.78^{a}	0.51^{ab}	2.29^{a}
M_3-DDK 1029 (WOP)	11.53^{b}	1.79^{a}	0.53^{ab}	2.32^{a}
M_4-DDK 1029 (WP)	12.05^{a}	1.87^{a}	0.56^{a}	2.43^{a}
Sub plots:- (Four planting geometries)				
S_1- 30 × 15 cm	12.13^{a}	1.90^{a}	0.60^{a}	2.50^{a}
S_2- 45 × 15 cm	11.71^{b}	1.75^{ab}	0.50^{b}	2.24^{bc}
S_3- 20 × 20 cm	11.89^{ab}	1.83^{ab}	0.56^{a}	2.39^{ab}
S_4- 20 cm (RPP)	10.91^{c}	1.59^{b}	0.41^{c}	2.00^{c}
Interaction (M × S)				
M_1S_1	11.65^{d-f}	1.78^{a-c}	0.57^{bc}	2.35^{b-e}
M_1S_2	11.05^{gh}	1.58^{cd}	0.42^{ef}	2.00^{gh}
M_1S_3	11.26^{fg}	1.64^{b-d}	0.53^{cd}	2.17^{d-g}
M_1S_4	10.37^{i}	1.47^{d}	0.38^{f}	1.85^{h}
M_2S_1	12.32^{ab}	1.87^{ab}	0.58^{bc}	2.45^{a-c}
M_2S_2	12.11^{bc}	1.77^{a-c}	0.51^{d}	2.28^{b-f}
M_2S_3	12.17^{a-c}	1.84^{a-c}	0.54^{cd}	2.38^{a-d}
M_2S_4	11.25^{fg}	1.64^{b-d}	0.40^{ef}	2.04^{f-h}
M_3S_1	12.01^{b-d}	1.92^{a}	0.61^{ab}	2.53^{a-c}
M_3S_2	11.51^{ef}	1.76^{a-c}	0.51^{d}	2.27^{c-f}
M_3S_3	11.83^{c-e}	1.87^{ab}	0.58^{bc}	2.45^{a-c}
M_3S_4	10.79^{hi}	1.61^{b-d}	0.41^{ef}	2.02^{f-h}
M_4S_1	12.54^{a}	2.01^{a}	0.64^{a}	2.65^{a}
M_4S_2	12.16^{a-c}	1.87^{ab}	0.54^{cd}	2.41^{a-d}
M_4S_3	12.28^{ab}	1.95^{a}	0.60^{ab}	2.55^{ab}
M_4S_4	11.24^{fg}	1.64^{b-d}	0.45^{e}	2.09^{e-h}

Mean followed by the same letter(s) did not differ significantly by DMRT (p= 0.05)

seed priming acts as a catalyst for several physiological and biochemical processes, creating a conducive environment for higher grain protein content and improved protein quality in emmer wheat. These results are in conformity with the finding of Muchhadiya et al (2021).

Nitrogen content in grain, straw and total content (%): Primed seeds (M_4) recorded higher grain, straw and significantly higher total nitrogen content (1.87, 0.56 and 2.43 %, respectively) which was on par with M_3 and M_2. The lower nitrogen content in grain, straw and significantly lower total nitrogen content (1.62, 0.48 and 2.09 %, respectively) was in un-primed seeds (M_1) (Table 2). These might be due to seed priming with cow dung and cow urine contributes to higher grain nitrogen content in wheat through a combination of nutrient enrichment, beneficial microbial activity, hormonal stimulation, improved root development, enhanced water retention, reduced nitrogen loss and increased stress tolerance. This holistic approach harnesses the organic properties of these substances to optimize nitrogen availability and utilization for improved wheat crop performance. This was in conformity with the finding of (Sharma 2020).

Phosphorous content in grain, straw and total content (%): Primed seeds (M_4) recorded significantly higher grain, straw and total phosphorous content (0.34, 0.17 and 0.50 %, respectively). The significantly lower grain, straw and total phosphorous content (0.30, 0.13 and 0.43 %, respectively) was recorded in un-primed seeds (M_1) (Table 3). These might be due to organic substances offer a comprehensive approach to enhance phosphorus availability and utilization during key growth stages. Similar type of results was recorded by (Sharma 2020).

Potassium content in grain, straw and total content (%): Primed seeds recorded higher grain, straw and total potassium content (0.46, 1.30 and 1.76 %, respectively) as compared to un-primed seeds (0.44, 1.23 and 1.66, respectively) (Table 3). These might be due to organic substances provide a holistic approach to improve potassium availability, offering insights for sustainable and quality-focused agricultural practices. Similar type of results was recorded by (Sharma 2020).

Nutrient Uptake by Emmer Wheat as Influenced by Seed Priming

Nitrogen uptake in grain, straw and total uptake (kg ha^{-1}): Primed seeds (M_4) recorded significantly higher nitrogen uptake in grain, straw and total uptake. The significantly lower nitrogen uptake in grain, straw and total uptake was in un-primed seeds (Table 4). This may be due to seed treatment helps in increasing the absorbing surface of root system causes increased plant growth and yield attributes and nutrient absorption by roots (N, P_2O_5 and K_2O). This was in conformity with the finding of Zheng et al (2013).

Phosphorous uptake in grain, straw and total uptake (kg ha^{-1}): Primed seeds (M_4) recorded significantly higher phosphorous uptake in grain, straw and total uptake (as compared to un-primed seeds (Table 4). These might be due to higher grain yield, straw yield, higher phosphorous content in grain, straw and total phosphorous content was in primed seeds as compared to un-primed seeds. This was in conformity with the finding of (Kumar et al 2021).

Potassium uptake in grain, straw and total uptake (kg ha^{-1}): Primed seeds (M_4) recorded significantly higher potassium uptake in grain, straw and total potassium uptake as compared to un-primed seeds (Table 4). This may be due to seed treatment helps in increasing the absorbing surface of root system causes increased plant growth and yield attributes and nutrient absorption by roots (N, P_2O_5 and K_2O). This was in conformity with the finding of Zheng et al (2013).

Influence of seed priming on soil chemical properties after harvest of emmer wheat crop: The chemical properties of soil *viz.,* soil reaction (pH), electrical conductivity (dS m^{-1}) and organic carbon (%) of the soil after harvest of crop as influenced by seed priming are furnished. The seed priming, did not significantly influence the soil pH, electrical conductivity (dS m^{-1}) and organic carbon (%) (Table 5). This lack of significant influence on soil chemical properties through seed priming may be attributed to the limited impact observed in this particular context. Similar results were obtained by Sharma (2022).

Influence of Seed Priming on Available Nitrogen, Phosphorus and Potassium Status in Soil after Harvest of the Emmer Wheat Crop

Available nitrogen in soil: Seed priming significantly influenced the available nitrogen in the soil. Un-primed seeds recorded significantly higher available nitrogen in soil (246.30 kg ha^{-1}) and was on par with M_1 ^{1}. The significantly lower available nitrogen in soil was in primed seeds (M_2 and M_4) (234.70 and 237.64 kg ha^{-1}, respectively) (Table 5). This could be attributed to the increased nitrogen uptake in primed seeds as compared to un-primed seeds. Similar results were obtained by Dhar et al (2016).

Available phosphorous in soil: The available phosphorus in the soil was significantly influenced by seed priming. Un-primed seeds recorded significantly higher available phosphorous in soil (30.24 kg ha^{-1}) and was on par with M_3. The, significantly lower available phosphorous in soil was recorded in primed seeds M_2 and M_4 (Table 5). This could be attributed to the enhanced phosphorus uptake in primed seeds as compared to un-primed seeds (Sharma 2022).

Available potassium in soil: The seed priming did not significantly influence the available potassium in soil. The available potassium was higher in un-primed seeds (292.00 kg ha^{-1}) as compared to primed seeds (284.83 kg ha^{-1}) (Table 5).

Yield and Yield Attributes of Emmer Wheat as Influence by different Planting Geometries

Number of effective tillers (m^{-2}): Significantly higher number of effective tillers (452.85 m^{-2}) were recorded in 30 × 15 cm planting geometry (S_1) and significantly lower effective tillers were in S_2 (45 × 15 cm planting geometry - 357.61 m^{-2}) (Table 1). These might be due to wider spacing facilitates plants for better utilization of nutrient, water, light and space leading to produced maximum number of effective tillers per unit area than conventional practices and under wider row spacing number of plant population should be decreases as compared to narrow row spacing. Similar results were obtained by Muchhadiya et al (2021).

Grain yield (q ha^{-1}): Significantly higher grain yield (40.20 q ha^{-1}) was recorded by the 30 × 15 cm planting geometry (S_1). However, was on par with (S_3) 20 × 20 cm planting geometry. Significantly lower grain yield was in (S_4) 20 cm (RPP) planting geometry (31.45 q ha^{-1}) (Table 1). These might be due to higher yield attributes *viz.,* number of effective tillers, number of grains per spike, spike weight, grain weight per spike and thousand grain weight was recorded in wider row spacing as compared to conventional practices. Similar results were obtained by Haque et al (2015).

Straw yield (q ha^{-1}): The 30 × 15 cm planting geometry (S_1)

Table 3. Phosphorous and potassium content of emmer wheat as influenced by seed priming and different planting geometries

Treatment	Phosphorous content in (%)			Potassium content in (%)		
	Grain	Straw	Total	Grain	Straw	Total
Main plots:- (Two genotypes with and without seed priming)						
M_1-Gokak local (WOP)	0.30^{c}	0.13^{b}	0.43^{d}	0.44^{a}	1.23^{a}	1.66^{a}
M_2- Gokak local (WP)	0.31^{bc}	0.14^{b}	0.45^{c}	0.44^{a}	1.27^{a}	1.71^{a}
M_3-DDK 1029 (WOP)	0.32^{b}	0.16^{a}	0.48^{b}	0.45^{a}	1.26^{a}	1.71^{a}
M_4-DDK 1029 (WP)	0.34^{a}	0.17^{a}	0.50^{a}	0.46^{a}	1.30^{a}	1.76^{a}
Sub plots:- (Four planting geometries)						
S_1- 30 × 15 cm	0.34^{a}	0.16^{a}	0.50^{a}	0.46^{ab}	1.28^{a}	1.74^{a}
S_2- 45 × 15 cm	0.31^{a}	0.16^{a}	0.46^{b}	0.49^{a}	1.29^{a}	1.78^{a}
S_3- 20 × 20 cm	0.32^{a}	0.15^{ab}	0.47^{b}	0.43^{ab}	1.26^{a}	1.70^{a}
S_4- 20 cm (RPP)	0.30^{a}	0.14^{c}	0.44^{b}	0.40^{b}	1.22^{a}	1.62^{a}
Interaction (M × S)						
M_1S_1	0.31^{b-e}	0.14^{de}	0.45^{de}	0.46^{a-d}	1.25^{ab}	1.71^{a-c}
M_1S_2	0.29^{de}	0.14^{de}	0.43^{ef}	0.48^{a-c}	1.27^{ab}	1.75^{ab}
M_1S_3	0.30^{c-e}	0.13^{ef}	0.43^{ef}	0.43^{a-d}	1.23^{ab}	1.66^{a-c}
M_1S_4	0.28^{e}	0.12^{f}	0.40^{f}	0.38^{d}	1.15^{b}	1.53^{c}
M_2S_1	0.33^{a-d}	0.15^{cd}	0.48^{b-d}	0.44^{a-d}	1.27^{ab}	1.71^{a-c}
M_2S_2	0.30^{c-e}	0.15^{cd}	0.45^{de}	0.49^{ab}	1.29^{ab}	1.78^{ab}
M_2S_3	0.31^{b-e}	0.14^{de}	0.45^{de}	0.42^{a-d}	1.26^{ab}	1.68^{a-c}
M_2S_4	0.29^{de}	0.13^{ef}	0.42^{ef}	0.40^{cd}	1.25^{ab}	1.65^{a-c}
M_3S_1	0.35^{ab}	0.16^{bc}	0.51^{b}	0.47^{a-c}	1.29^{ab}	1.76^{ab}
M_3S_2	0.31^{b-e}	0.16^{bc}	0.47^{cd}	0.48^{a-c}	1.30^{a}	1.78^{a-c}
M_3S_3	0.33^{a-d}	0.15^{cd}	0.48^{b-d}	0.43^{a-d}	1.27^{ab}	1.70^{a-c}
M_3S_4	0.30^{c-e}	0.15^{cd}	0.45^{de}	0.41^{b-d}	1.19^{ab}	1.60^{bc}
M_4S_1	0.36^{a}	0.18^{a}	0.54^{a}	0.48^{a-c}	1.30^{a}	1.78^{ab}
M_4S_2	0.33^{a-d}	0.17^{ab}	0.50^{bc}	0.50^{a}	1.31^{a}	1.81^{a}
M_4S_3	0.34^{a-c}	0.16^{bc}	0.50^{bc}	0.45^{a-d}	1.29^{ab}	1.74^{ab}
M_4S_4	0.32^{a-e}	0.15^{cd}	0.47^{cd}	0.42^{a-d}	1.28^{ab}	1.70^{a-c}

Mean followed by the same letter(s) did not differ significantly by DMRT (p= 0.05)

recorded significantly higher straw yield (66.30 q ha^{-1}) and significantly lower straw yield was in (S_4) 20 cm planting geometry (57.52 q ha^{-1}) (Table 1). These might be due to reduction in straw yield at wider row spacing's were mainly be ascribed to the decrease in overall number of plants per unit area rather than number of tillers per hill at wider row spacing's. Wider row spacing permitted better performance per hill than narrow row spacing due to decreased competition between plant for nutrient, water, space and light but decreased overall grain and straw yields might be due to lesser plant biomass production at wider row spacing's. The results corroborate with the finding of Jayawardena and Abeysekera (2011).

Biological yield (q ha^{-1}): The 30 × 15 cm planting geometry (S_1) recorded significantly higher biological yield (106.50 q ha^{-1}) and was shown on par with S_3 (98.51 q ha^{-1}). However, significantly lower biological yield was in (S_4) 20 cm (RPP) planting geometry (88.96 q ha^{-1}) (Table 1). These might be due to higher grain and straw yields was recorded in wider row spacing as compared to conventional practices (Dhar et al 2016).

Quality Parameters of Emmer Wheat as Influenced by Planting Geometries

Grain crude protein content of emmer wheat: The 30 × 15 cm planting geometry (S_1) recorded significantly higher grain crude protein content (12.13 %) and on par with S_3 (11.89 %). Significantly lower grain crude protein content was in (S_4) 20 cm (RPP) planting geometry (10.91 %) (Table 2). This is due

Table 4. Nitrogen, phosphorous and potassium uptake by emmer wheat as influenced by seed priming and different planting geometries

Treatment	N uptake (kg ha^{-1})			P uptake (kg ha^{-1})			K uptake (kg ha^{-1})		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
Main plots:- (Two genotypes with and without seed priming)									
M_1-Gokak local (WOP)	53.91^{c}	28.21^{c}	82.12^{c}	9.67^{b}	7.82^{c}	17.48^{c}	14.30^{b}	72.25^{c}	86.55^{c}
M_2- Gokak local (WP)	64.20^{b}	31.23^{bc}	95.43^{b}	11.17^{b}	8.76^{bc}	19.93^{bc}	15.77^{b}	77.66^{b}	93.43^{b}
M_3-DDK 1029 (WOP)	63.43^{b}	32.58^{b}	96.01^{b}	11.38^{ab}	9.52^{ab}	20.90^{b}	15.75^{b}	77.59^{b}	93.34^{b}
M_4-DDK 1029 (WP)	73.38^{a}	36.01^{a}	109.39^{a}	12.98^{a}	10.56^{a}	23.54^{a}	17.68^{a}	82.96^{a}	100.64^{a}
Sub plots:- (Four planting geometries)									
S_1- 30 × 15 cm	76.60^{a}	39.88^{a}	116.48^{a}	13.62^{a}	10.49^{a}	24.11^{a}	18.62^{a}	84.84^{a}	103.46^{a}
S_2- 45 × 15 cm	61.19^{c}	29.80^{c}	91.00^{c}	10.44^{c}	9.32^{b}	19.76^{c}	16.39^{b}	77.72^{b}	94.11^{b}
S_3- 20 × 20 cm	66.85^{b}	34.74^{b}	101.59^{b}	11.76^{b}	8.94^{c}	20.71^{b}	15.86^{b}	77.87^{b}	93.73^{b}
S_4- 20 cm (RPP)	50.28^{d}	23.60^{d}	73.88^{d}	9.37^{d}	7.90^{d}	17.27^{d}	12.65^{c}	70.02^{c}	82.66^{c}
Interaction (M × S)									
M_1S_1	66.04^{de}	35.94^{d}	101.98^{c}	11.12^{ef}	8.83^{f}	19.95^{e}	16.32^{e}	78.83^{d}	95.15^{c}
M_1S_2	49.83^{h}	24.39^{i}	74.22^{g}	9.22^{hi}	8.13^{g}	17.36^{h}	15.23^{f}	73.88^{ef}	89.12^{e}
M_1S_3	56.49^{g}	31.70^{f}	88.19^{e}	10.18^{g}	7.73^{h}	17.91^{gh}	14.57^{g}	73.34^{f}	87.91^{e}
M_1S_4	43.28^{i}	20.80^{k}	64.08^{h}	8.15^{j}	6.57^{i}	14.72^{j}	11.08^{j}	62.93^{h}	74.02^{g}
M_2S_1	75.54^{b}	38.36^{c}	113.89^{b}	14.16^{b}	9.96^{cd}	24.13^{b}	18.94^{b}	84.23^{bc}	103.17^{b}
M_2S_2	62.73^{f}	30.20^{g}	92.93^{d}	10.17^{g}	8.89^{ef}	19.06^{f}	16.52^{e}	76.45^{de}	92.97^{cd}
M_2S_3	68.46^{cd}	33.34^{e}	101.80^{c}	11.36^{de}	8.70^{f}	20.06^{e}	15.29^{f}	77.98^{d}	93.27^{cd}
M_2S_4	50.08^{h}	23.02^{j}	73.10^{g}	8.98^{i}	7.49^{h}	16.47^{i}	12.34^{i}	71.96^{f}	84.30^{f}
M_3S_1	76.34^{b}	40.07^{b}	116.41^{b}	13.46^{c}	10.55^{b}	24.01^{b}	18.28^{c}	84.82^{b}	103.10^{b}
M_3S_2	62.88^{f}	30.69^{fg}	93.57^{d}	10.77^{f}	9.64^{d}	20.42^{de}	16.33^{e}	78.29^{d}	94.62^{c}
M_3S_3	64.33^{ef}	35.80^{d}	100.13^{c}	11.76^{d}	9.23^{e}	20.99^{d}	15.36^{f}	78.35^{d}	93.71^{cd}
M_3S_4	50.16^{h}	23.76^{ij}	73.92^{g}	9.55^{h}	8.65^{f}	18.19^{g}	13.04^{h}	68.90^{g}	81.94^{f}
M_4S_1	88.47^{a}	45.15^{a}	133.63^{a}	15.75^{a}	12.62^{a}	28.38^{a}	20.95^{a}	91.49^{a}	112.44^{a}
M_4S_2	69.34^{c}	33.94^{e}	103.27^{c}	11.61^{d}	10.61^{b}	22.22^{c}	17.45^{d}	82.27^{bc}	99.73^{b}
M_4S_3	78.12^{b}	38.13^{c}	116.25^{b}	13.75^{bc}	10.11^{c}	23.86^{b}	18.21^{c}	81.81^{c}	100.02^{b}
M_4S_4	57.58^{g}	26.82^{h}	84.40^{f}	10.80^{f}	8.90^{ef}	19.70^{ef}	14.11^{g}	76.27^{de}	90.38^{de}

Mean followed by the same letter(s) did not differ significantly by DMRT ($p = 0.05$)

to the higher uptake of nitrogen in turn resulting in higher grain crude protein content. Higher protein content was also recorded in the system of wheat intensification when compared to normal practices also highlighted by Muchhadiya et al (2021).

Nitrogen content in grain, straw and total content (%): The 30 × 15 cm planting geometry (S_1) exhibited significantly higher nitrogen content in grain, straw and total content (1.90, 0.60 and 2.50 %, respectively) which was comparable with S_3 (1.83, 0.56 and 2.39 %, respectively). Conversely, significantly lower nitrogen content in grain, straw and total content was observed in the 20 cm planting geometry (S_4) (Table 2). The right planting geometry promotes efficient nutrient uptake, minimizes nutrient competition, enhances soil conditions for nitrogen availability and reduces nitrogen loss, all of which collectively contribute to higher nitrogen content in wheat grain. Similar results were obtained by Sharma (2020).

Phosphorous content in grain, straw and total content (%): Numerically higher phosphorous content in grain, straw and significantly higher total phosphorous content was recorded in 30 × 15 cm planting geometry (0.34, 0.16 and 0.50 %, respectively). The significantly lower phosphorous content in grain, straw and total content was recorded in 20 cm (RPP) planting geometry (0.30, 0.14 and 0.44 %, respectively) (Table 3). The right planting geometry supports efficient phosphorus uptake by promoting optimal root development, minimizing competition, enhancing fertilizer

Table 5. Soil chemical properties and nutrient available status in soil after harvest of emmer wheat as influenced by seed priming and different planting geometries

Treatment	Soil pH	EC (dS m^{-1})	OC (%)	Avai. N (kg ha^{-1})	Avai. P (kg ha^{-1})	Avai. K (kg ha^{-1})
Main plots:- (Two genotypes with and without seed priming)						
M_1-Gokak local (WOP)	7.80^{a}	0.37^{a}	0.54^{a}	240.15^{ab}	30.24^{a}	292.00^{a}
M_2- Gokak local (WP)	7.73^{a}	0.37^{a}	0.55^{a}	234.70^{b}	27.82^{b}	284.83^{a}
M_3-DDK 1029 (WOP)	7.80^{a}	0.37^{a}	0.54^{a}	246.30^{a}	29.21^{ab}	290.63^{a}
M_4-DDK 1029 (WP)	7.75^{a}	0.37^{a}	0.54^{a}	237.64^{b}	28.11^{b}	286.42^{a}
Sub plots:- (Four planting geometries)						
S_1- 30 × 15 cm	7.80^{a}	0.37^{a}	0.54^{a}	234.52^{b}	26.20^{d}	274.10^{b}
S_2- 45 × 15 cm	7.75^{a}	0.37^{a}	0.54^{a}	241.23^{ab}	29.55^{b}	293.18^{a}
S_3- 20 × 20 cm	7.78^{a}	0.37^{a}	0.54^{a}	235.93^{b}	27.89^{c}	287.80^{a}
S_4- 20 cm (RPP)	7.75^{a}	0.38^{a}	0.55^{a}	247.12^{a}	31.74^{a}	298.81^{a}
Interaction (M × S)						
M_1S_1	7.80^{ab}	0.37^{ab}	0.55^{ab}	234.61^{ef}	27.39^{f-h}	281.90^{de}
M_1S_2	7.70^{ab}	0.38^{a}	0.54^{bc}	241.90^{b-e}	31.58^{ab}	295.40^{a-c}
M_1S_3	7.80^{ab}	0.36^{bc}	0.53^{c}	235.40^{ef}	29.41^{c-e}	290.54^{a-e}
M_1S_4	7.90^{a}	0.37^{ab}	0.55^{ab}	248.67^{ab}	32.59^{a}	300.14^{ab}
M_2S_1	7.90^{a}	0.37^{ab}	0.54^{bc}	234.60^{ef}	25.48^{i}	269.36^{f}
M_2S_2	7.70^{ab}	0.38^{a}	0.55^{ab}	234.10^{ef}	28.16^{e-g}	289.90^{a-e}
M_2S_3	7.70^{ab}	0.36^{bc}	0.54^{bc}	228.70^{f}	27.16^{gh}	284.39^{c-e}
M_2S_4	7.60^{b}	0.38^{a}	0.56^{a}	241.39^{b-e}	30.48^{bc}	295.68^{a-c}
M_3S_1	7.90^{a}	0.36^{bc}	0.53^{c}	239.40^{cde}	26.45^{hi}	278.67^{ef}
M_3S_2	7.80^{ab}	0.35^{c}	0.54^{bc}	248.30^{ab}	29.48^{cd}	293.89^{a-d}
M_3S_3	7.70^{ab}	0.37^{ab}	0.53^{c}	243.90^{b-d}	28.46^{d-f}	288.45^{b-e}
M_3S_4	7.80^{ab}	0.38^{a}	0.56^{a}	253.61^{a}	32.45^{a}	301.50^{a}
M_4S_1	7.60^{b}	0.36^{bc}	0.53^{c}	229.45^{f}	25.48^{i}	266.45^{f}
M_4S_2	7.80^{ab}	0.36^{bc}	0.54^{bc}	240.60^{b-e}	28.97^{de}	293.51^{a-d}
M_4S_3	7.90^{a}	0.37^{ab}	0.54^{bc}	235.70^{d-f}	26.54^{hi}	287.80^{b-e}
M_4S_4	7.70^{ab}	0.38^{a}	0.53^{c}	244.80^{bc}	31.45^{ab}	297.90^{ab}

Mean followed by the same letter(s) did not differ significantly by DMRT (p= 0.05)

utilization, reducing soil fixation, encouraging beneficial associations, optimizing plant density and improving water use efficiency all of which collectively contribute to higher phosphorus content in wheat grain. Similar results were obtained by Sharma (2020).

Potassium content in grain, straw and total content (%): Planting geometry of 45 × 15 cm recorded significantly higher grain potassium content and numerically higher straw and total potassium content (0.49, 1.29 and 1.78 %, respectively) as compared to 20 cm (RPP) planting geometry (Table 3). The right planting geometry supports efficient potassium uptake by promoting optimal root development, minimizing competition, enhancing fertilizer utilization, reducing soil fixation, facilitating root soil interactions, optimizing plant density and improving water use efficiency all of which contribute to higher potassium content in wheat grain.

Nutrient Uptake by Emmer Wheat as Influenced by Planting Geometries

Nitrogen uptake in grain, straw and total N uptake (kg ha^{-1}): The 30 × 15 cm planting geometry (S_1) recorded significantly higher nitrogen uptake in grain, straw and total N uptake (76.60, 39.88 and 116.48 kg ha^{-1}, respectively). Significantly lower nitrogen uptake in grain, straw and total N uptake was in (S_4) 20 cm (RPP) planting geometry (50.28, 23.60 and 73.88 kg ha^{-1}, respectively) (Table 4). The right planting geometry supports efficient nitrogen uptake by promoting optimal root development, minimizing competition, enhancing fertilizer utilization, reducing nitrogen loss, facilitating symbiotic nitrogen fixation, optimizing plant density and improving water use efficiency all of which contribute to higher nitrogen uptake by wheat (Chatterjee et al 2016).

Phosphorous uptake in grain, straw and total P uptake (kg ha^{-1}): Significantly higher phosphorus uptake in grain, straw and total uptake (13.62, 10.49 and 24.11 kg ha^{-1}, respectively) was recorded by the 30 × 15 cm planting geometry (S_1). The significantly lower phosphorous uptake in grain, straw and total uptake was recorded in (S_4) 20 cm (RPP) planting geometry (9.37, 7.90 and 17.27 kg ha^{-1}, respectively) (Table 4).

Potassium uptake in grain, straw and total K uptake (kg ha^{-1}): The 30 × 15 cm planting geometry (S_1) recorded significantly higher potassium uptake in grain, straw and total uptake (18.62, 84.84 and 103.46 kg ha^{-1}, respectively) and significantly lower potassium uptake in grain, straw and total uptake was in (S_4) 20 cm (RPP) planting geometry (12.65, 70.02 and 82.66 kg ha^{-1}, respectively) (Table 4). Similar results were obtained by Chatterjee et al (2016).

Influence of planting geometry on soil chemical properties after harvest of emmer wheat crop

The planting geometries, did not significantly influence the soil pH, electrical conductivity (dS m^{-1}) and organic carbon (%) (Table 5). This lack of significant influence on soil chemical properties through planting geometries may be attributed to the limited impact observed in this particular context. The non-significant impact of planting geometries on soil chemical properties post-harvest may be due to the inherent stability of the soil system under the studied configurations. Similar results were obtained by Sharma (2020).

Influence of planting geometries on available nitrogen, phosphorus and potassium status in soil after harvest of the emmer wheat crop

The 20 cm (RPP) planting geometry (S_4) recorded significantly higher available nitrogen, phosphorous and potassium in soil (247.12, 31.74 and 298.81 kg ha^{-1}, respectively) and was found on par with S_2 . In converse, significantly lower available nitrogen, phosphorous and potassium in soil was recorded in 30 × 15 cm planting geometry (S_1) (234.52, 26.20 and 274.10 kg ha^{-1}, respectively). These might be due to lower nutrients uptake *viz.,* nitrogen, phosphorous and potassium was recorded in 20 cm (RPP) planting geometry as compared to other planting geometries. Similar results were obtained by Dharet al (2015).

Table 6. Correlation coefficient between grain protein, nitrogen, phosphorous and potassium content and economics of emmer wheat

Parameter	Grain protein content (%)	Total grain N content (%)	Total grain P content (%)	Total grain K content (%)	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio
Grain protein content (%)	1						
Total grain N content (%)	0.937**	1					
Total grain P content (%)	0.781**	0.873**	1				
Total grain K content (%)	0.734**	0.670**	0.690**	1			
Gross returns (Rs. ha^{-1})	0.875**	0.912**	0.833**	0.550**	1		
Net returns (Rs. ha^{-1})	0.900**	0.932**	0.803**	0.644**	0.972**	1	
B:C ratio	0.880**	0.9070**	0.742**	0.688**	0.909**	0.9808**	1

**Significant at 5 %

Combined influence of seed priming and planting geometries on yield, quality parameters and nutrient uptake by emmer wheat

Yield and yield attributes: Primed seeds sown with 30 × 15 cm planting geometry (M_4S_1) recorded significantly higher grain (44.13 q ha^{-1}) and straw yields (70.64 q ha^{-1}) and grain yield was found on par with M_4S_3 , M_3S_1 , M_2S_1, M_2S_3 and M_1S_1 (Table 1). The significantly lower grain yield was in M_1S_4 (conventional line sown at 20 cm (RPP) planting geometry). This increase in grain yield might be due to the synergistic effect of seed priming with bio-formulation along with optimum planting geometry and increased yield attributes *viz.,* number of effective tillers (463.83 m^{-2}), number of grain per spike, spike weight, grain weight per spike, thousand grain weight and spike length and is on par with M_2S_1, M_4S_3 and M_4S_2. These findings are consistent with the outcomes reported by Haqueet al (2015) and Chatterjee et al (2016).

Grain crude protein content: The primed seeds sown with 30 × 15 cm planting geometry (M_4S_1) recorded significantly higher grain crude protein content (12.54 %) and was on par with M_4S_2 , M_4S_3 , M_2S_1 and M_2S_3 (Table 2). The significantly lower grain crude protein content was recorded in M_1S_4 (un-primed seed with 20 cm (RPP) planting geometry). This was due to higher uptake of nitrogen in grain increasing the grain protein content.

Nitrogen, phosphorous and potassium content in grain, straw and total content of emmer wheat: The primed seeds sown with 30 × 15 cm planting geometry (M_4S_1) recorded numerically higher nitrogen and phosphorous content in grain, straw and total content. However, higher potassium content in grain, straw and total content was recorded in primed seeds sown with 45 × 15 cm planting geometry (M_4S_1) as compared to un-primed seeds sown with 20 cm (RPP) planting geometries (Table 2 , 3). These might be due to the combination of seed priming and strategic planting geometries positively influences nutrient content in wheat grain by improving germination efficiency, optimizing root development, enhancing nutrient uptake systems, minimizing competition, facilitating soil-root interactions, promoting efficient fertilizer utilization and reducing nutrient loss. This is in accordance with the findings of Sharma (2020)

Nutrient uptake patterns of emmer wheat: The primed seeds sown with 30 × 15 cm planting geometry (M_4S_1) recorded significantly highest uptake of N, P and K by grain, straw and total uptake and lowest uptake of N, P and K was recorded in M_1S_4 (un-primed seed with 20 cm (RPP- planting geometry) (Table 4). The system of wheat intensification recorded higher uptake of N, P and K as compared to conventional method of cultivation which could be ascribed to better vegetative and reproductive growth under SWI method of cultivation. Wider spacing reduced the above and below ground competition, well developed and healthy root system causes increase N, P and K uptakes. Further primed seed recorded higher nutrient uptake than un-primed seed. This may be due to the fact that seed treatment helps in increasing the absorbing surface of root system causes increased plant growth and yield attributes and nutrient absorption by roots (N, P_2O_5 and K_2O). This is in accordance with the findings of Chandrapala et al (2010) and Zheng et al (2013).

Soil fertility status as influenced by varied planting geometries and seed priming: Combination of un-primed seeds sown with 20 cm (RPP) planting geometry (M_3S_4) recorded significantly higher soil available N , P , and K , after harvest of emmer wheat and it was on par with M_3S_2 , M_1S_4 , M_1S_2 and M_4S_4 . The significantly lower soil available N, P and K after harvest of wheat was in M_4S_1 and M_2S_1 (primed seed with 30 × 15 cm planting geometry) (Table 5). This might be due to higher uptake of N, P and K in primed seed sown with 30 × 15 cm planting geometry. Similar results were obtained by Sharma (2022).

Influence of seed priming and planting geometries on economics: Among the main plots, primed seeds (M_4) recorded significantly higher gross return (₹1,41,915 ha^{-1}), net returns (₹92,033 ha^{-1}), and B:C ratio (2.88) and was on par with M_2 and M_3. The significantly lower gross returns, net

Table 7. Correlation coefficient between Macro nutrient uptake by emmer wheat and available macro nutrient in soil after harvest of emmer wheat

Parameter	Total N uptake (kg ha^{-1})	Total P uptake (kg ha^{-1})	Total K uptake (kg ha^{-1})	Available N in soil (kg ha^{-1})	Available P in soil (kg ha^{-1})	Available K in soil (kg ha^{-1})
Total N uptake (kg ha^{-1})	1					
Total K uptake (kg ha^{-1})	0.961**	1				
Total K uptake (kg ha^{-1})	0.958**	0.959**	1			
Available N in soil (kg ha^{-1})	-0.669**	-0.512**	-0.625**	1		
Available P in soil (kg ha^{-1})	-0.937**	-0.830**	-0.874**	0.795**	1	
Available K in soil (kg ha^{-1})	-0.870**	-0.817**	-0.838**	0.745**	0.911**	1

**Significant at 5 %

Table 8. Economics of emmer wheat as influenced by seed priming and different planting geometries

Treatment	Cost of cultivation (Rs ha^{-1})	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	B:C ratio
Main plots:- (Two genotypes with and without seed priming)				
M_1-Gokak local (WOP)	48400^a	121192^b	72792^b	2.53^b
M_2- Gokak local (WP)	49022^a	133253^{ab}	84231^{ab}	2.76^{ab}
M_3-DDK 1029 (WOP)	48511^a	129284^{ab}	80773^{ab}	2.70^{ab}
M_4-DDK 1029 (WP)	49883^a	141915^a	92033^a	2.88^a
Sub plots:- (Four planting geometries)				
S_1- 30 × 15 cm	46247^b	147989^a	101742^a	3.20^a
S_2- 45 × 15 cm	45834^b	125890^c	80056^c	2.75^c
S_3- 20 × 20 cm	47162^b	135377^b	88215^b	2.87^b
S_4- 20 cm (RPP)	56572^a	116388^d	59816^d	2.06^d
Interaction (M × S)				
M_1S_1	46082^d	134009^{ef}	87927^{ef}	2.91^b
M_1S_2	45702^d	116698^h	70996^i	2.55^h
M_1S_3	46234^d	125807^g	79573^h	2.72^g
M_1S_4	55582^b	108254^i	52672^l	1.95^k
M_2S_1	46362^d	155474^b	109112^b	3.35^b
M_2S_2	45926^d	125963^g	80037^h	2.74^{fg}
M_2S_3	46536^d	136344de	89808^e	2.93^{de}
M_2S_4	57262^{ab}	115229^h	57967^k	2.01^{jk}
M_3S_1	46132^d	140234^d	94102^d	3.04^c
M_3S_2	45742^d	129102^{fg}	83360^g	2.82^{ef}
M_3S_3	46288^d	130965^f	84677^{fg}	2.83^{ef}
M_3S_4	55882^{ab}	116836^h	60954^k	2.09^{ij}
M_4S_1	46412^d	162240^a	115828^a	3.50^a
M_4S_2	45966^d	131798^{ef}	85832^{fg}	2.87^e
M_4S_3	49590^c	148392^c	98802^c	2.99^{cd}
M_4S_4	57562^a	125232^g	67670j	2.18^i

Mean followed by the same letter(s) did not differ significantly by DMRT (p= 0.05)

returns and B:C ratio was recorded in un-primed seeds (M_1). Within the sub plot, 30 × 15 cm planting geometry (S_1) recorded significantly higher gross return (₹1,47,989 ha^{-1}), net returns (₹1,01,742 ha^{-1}), and B:C ratio (3.20) when compared to (S_4) conventional line sown at 20 cm (RPP) planting geometry. Among the interaction effect, primed seeds sown with 30 × 15 cm planting geometry (M_4S_1) recorded significantly higher gross return (1,62,240 ha^{-1}), net returns (1,15,828 ha^{-1}), and B:C ratio (3.50) (Table 8) when compared to un-primed seeds with conventional line sown at 20 cm (RPP) planting geometry (M_1S_4). This might be due to lower usage of external input *viz.,* very low seed rate, higher grain yield, straw yield and less labour requirement *etc.* Similar type of results was also obtained by Kumar et al (2015) and Bhargava et al (2016).

CONCLUSION

Among the different treatment combinations, primed seeds sown with 30 × 15 cm planting geometry recorded significantly increased number of effective tillers, grain yield, straw yield, biological yield, grain crude protein content, macro nutrients content with greater uptake and higher economics. Thus, system of wheat intensification is best suitable option for resource poor farmers for getting higher yield and profit in irrigated ecosystem of Northern Dry Zone of Karnataka (Zone-3).

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Received 01 July, 2024; Accepted 21 September, 2024

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