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Effect of Seed Priming and Plant Geometry on the Growth and Productivity of Emmer Wheat (*Triticum dicoccum* L.)

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Abstract

A field experiment was conducted at Research field of Ugar Khurd, Belangavi, Dharwad, Karnataka, India during *rabi* season of October, 2022–February, 2023 under irrigated ecosystem on deep clay soil to study the system of wheat intensification for higher productivity of emmer wheat (*Triticum dicoccum* L.). The experiment was laid out in split plots design with three replications. The treatments comprised of two genotypes in main plot viz., Gokak local and DDK 1029 with and without seed priming and four planting geometries in Sub-plots viz., 30×15 cm^2, 45×15 cm^2, 20×20 cm^2 and 20 cm^2 (Recommended Package of Practices). The result indicated that primed seeds recorded significantly higher grain yield (3853 kg ha^{-1}), straw yield (6426 kg ha^{-1}), gross returns (₹ 1,41,915 ha^{-1}), net returns (₹ 92,033 ha^{-1}) and B:C ratio (2.88) as compared to un-primed seeds. The sowing of emmer wheat in 30×15 cm^2 planting geometry recorded significantly higher grain yield (4020 kg ha^{-1}), straw yield (6630 kg ha^{-1}), gross returns (₹ 1,47,989 ha^{-1}), net returns (₹ 1,01,742 ha^{-1}) and B:C ratio (3.20) as compared other planting geometries. The combination of primed seeds sown with 30×15 cm^2 planting geometry recorded significantly higher grain yield (4413 kg ha^{-1}), straw yield (7064 kg ha^{-1}), gross returns (₹ 1,62,240 ha^{-1}), net returns (₹ 1,15,828 ha^{-1}) and B:C ratio (3.50) as compared to other treatment combinations.

Keywords: Emmer wheat, planting geometries, seed priming, SWI, yield

1. Introduction

Emmer wheat (*Triticum dicoccum* L.) is grown on a limited scale in Gujarat, Maharashtra and Karnataka, known as Popathiya, Samba and Khapli, meaning 'crusty,' respectively. Compared to bread wheat, emmer wheat varieties are notably rich in protein and complex carbohydrates (dietary fiber), promoting a prolonged feeling of fullness and aiding in weight loss. With excellent grain quality traits, it contains over 16% dietary fiber, facilitating carbohydrate digestion and regulating blood sugar levels, making it suitable for diabetics. Emmer wheat boasts a protein content of 11.8% to 15.3%, total carbohydrates ranging from 78.7% to 83.2% and is rich in polyphenols, providing protection against cancer, cardiovascular diseases and neurodegenerative conditions. Traditional products from emmer wheat varieties offer superior taste, texture and flavour (Singh, 2015).

In the past four decades, India has made remarkable strides in wheat production, maintaining its position as the world's second-largest producer. Wheat output has surged from 6.60 mt at the time of independence to an impressive 106.84 mt in 2021–22 (Anonymous, 2022). This significant increase is attributed to the widespread adoption of semi-dwarf Mexican wheat varieties, coupled with a substantial rise in inputs, particularly fertilizers and irrigation. Looking ahead, the global demand for wheat is projected to reach 840 mt by 2050 (Sharma et al., 2015).

In India, wheat cultivation spans 30.47 m ha, yielding an annual productivity of around 3507 kg ha^{-1} (Anonymous, 2022). While Punjab and Haryana lead in national wheat productivity, Uttar Pradesh contributes over 30% to the country's wheat production. In Karnataka, where wheat is cultivated in a hot tropical climate, covering 1.68 lakh ha with a production of 1.8 lakh tonnes and a productivity of 1078 kg ha^{-1} (Anonymous, 2021), there's room for improvement in productivity, offering an opportunity to boost wheat production, profitability and overall yields.

Over the past two decades, traditional wheat cultivation methods have seen declining productivity gains due to input dependence. The conventional broadcasting and continuous line sowing methods, while serving well for extensive tracts, suffer from drawbacks like non-uniform crop stands, leading to input dilution and reduced yields. Farmers are grappling with high input costs to adhere to recommended technologies for increased production. Exploring alternative crop establishment and management methods could enhance wheat productivity with proportionally lower production costs.

The System of Wheat Intensification (SWI) is an innovative cultivation technique enhancing soil conditions for wheat growth (Pradhan, 2007). Widely practiced in India, China, Ethiopia, Poland and the USA (Anonymous, India and USA, 2009), SWI focuses on root development and intensive care principles. Unlike conventional methods, SWI prioritizes proper nourishment, inter and intra-row spacing and holistic plant care throughout growth. This system, involving weed, insect and disease management, organic manure application and irrigation, resulted in a 54% yield increase and improved economic returns compared to conventional practices (Uphoff et al., 2011). The prevalent wheat cultivation system relies on more chemical fertilizers, higher seed rates, narrow spacing and additional treatments (Chatterjee et al., 2016).

The modified SWI, incorporating techniques like dibbling single seeds at wider spacing and seed priming, offers favourable conditions for wheat growth without the intensive labour and water requirements of traditional transplanting (Sharma, 2022). Seed priming not only accelerates plant emergence but also enhances crop vigour, yielding benefits in tillering, emergence, grain and straw yield and harvest index (Toklu et al., 2015). Despite the grim wheat productivity scenario in Karnataka, especially the northern region, the study aimed to focus on the seed priming and plant geometry in the modified SWI.

2. Materials and Methods

2.1. Experimental site and design

A field experiment was conducted during the *rabi* season of October, 2022–February, 2023 at the Research field of Ugar Khurd, Belagavi, Karnataka, India. Geographically it lies between 16° 38′ 30″ N latitude, 74° 49′ 39″ E longitude and at an altitude of 561 m above mean sea level (MSL). To explore the "System of Wheat Intensification for higher productivity of emmer wheat (*Triticum dicoccum* L.)" in an irrigated ecosystem with deep clay soil. The experimental soil exhibited a slightly saline pH (8.00), EC of 0.40 dS m^{-1}, low organic carbon (0.58%) and available nitrogen (279.1 kg ha^{-1}), but high available phosphorus (32.6 kg ha^{-1}) and potassium (371.2 kg ha^{-1}). Implemented in a split plot design with three replications, the experiment featured two genotypes (Gokak local and DDK 1029) with and without seed priming in the main plots and four planting geometries (S_1:30×15 cm^2; S_2:45×15 cm^2; S_3:20×20 cm^2; S_4:20 cm^2 (RPP)) in subplots.

2.2. Climate and weather conditions

In 2022, the annual rainfall was 731 mm over 60 days, with only 7 mm during the cropping period (November 2022–March 2023). Mean maximum temperatures ranged from 30.35°C (December) to 35.45°C (March), while mean minimum temperatures varied from 14.51°C (January) to 20.32°C (March). Mean relative humidity fluctuated between 68.39% (February 2023) and 85.00% (December). Minimal deviation in maximum temperature and relative humidity was observed compared to the past 25 years (Figure 1).

2.3. Seed priming procedure

A 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

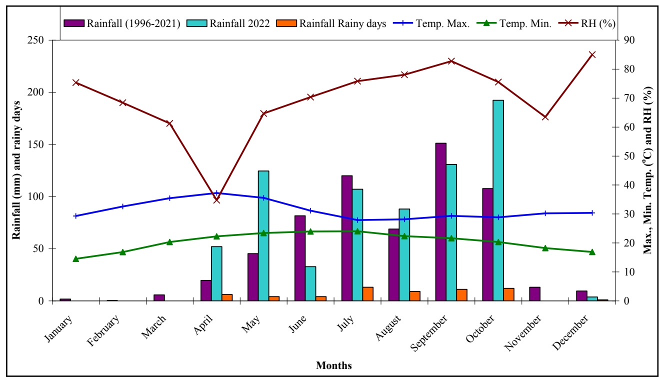

Figure 1: Monthly mean meteorological data during crop growth period (2022–23) and average of 25 years (1996–221) at research field of Ugar Khurd, Kagwad taluk, Belagavi

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 hours. Took the seeds out of the priming solution and dried in shade. Thereafter were sown directly in the field.

2.4. Recommended package of practice

The experimental plot was meticulously prepared, achieving fine tilth. Farm yard manure was evenly applied at 7.5 t ha^{-1} in 6.0×2.4 m^2 plots. Emmer wheat was sown using various planting geometries, receiving recommended fertilizer doses (60:30:20 kg N:P_2O_5:K_2O ha^{-1}). Nitrogen was split into two equal applications, at sowing and 30 days later. Phosphorus and potassium were applied entirely at sowing with half of the nitrogen. The crop, sown on November 15, 2022 and harvested on March 15, 2023, experienced a total rainfall of 731 mm over 60 rainy days during the cropping period. Irrigation was provided at 15-day intervals.

2.5. Estimating emmer wheat yield

Wheat was manually harvested, leaving two border rows unharvested in both directions and 0.5 m in the longitudinal direction. The harvested grain, dried to proper moisture content in sunlight, was weighed to determine the economic yield. Harvesting was conducted from the net plot, and the yield was expressed in quintals per hectare.

2.6. Statistical analysis

Recorded data were statistically analysed using Fisher's ANOVA for the split plot design, following Gomez and Gomez (1984). Standard error of mean and coefficient of variability were computed for each observed set. The mean values of main plot, sub plot and interaction effects were individually analysed via Duncan's Multiple Range Test (DMRT) using corresponding error mean sum of squares and degrees of freedom values in OP-STAT program.

3. Results and Discussion

3.1. Influence of seed priming on growth, yield and yield attributes and economics of emmer wheat

3.1.1. Growth parameters of emmer wheat as influenced by seed priming

The germination percentage and seedling vigour index of emmer wheat was significantly influenced by seed priming in system of wheat intensification. Primed seeds resulted significantly higher germination percentage (92.98) and seedling vigour index (2009.16) as compared to un-primed seeds (88.73% and 1854.51, respectively) (Table 1). It is already known that priming leads to completion of first two germination phases during the priming process itself and hence after sowing, primed seeds enter immediately into the third phase of germination and radicle emergence once rehydrated. This could be the reason for achieving higher germination percentage in emmer wheat. Additionally, cow urine and cow dung are rich sources of physiologically active substances, including growth regulators, nutrients, trace elements and heightened enzyme activity such as amylase, protease and lipase. These bioactive components play a crucial role in breaking down micro molecules, facilitating the growth and development of the embryo. Consequently, this contributes to the early and superior growth of emmer wheat seedlings. Comparable findings were reported by Kamalam and Rajappan (1989) and Dell and Tritto (1990).

Primed seeds recorded significantly lower plant height (33.87, 83.78, 97.47 and 98.45 cm^2 at 30, 60, 90 and at harvest, respectively) and lodging score (195%) as compared to un-primed seeds (39.02, 88.53, 101.15 and 102.65 cm^2 and 3.58%, respectively) (Table 1). This profound effect of seed treatment with the specific organic formulation on the plant height of the crop has been attributed due to the fact the cow urine contains physiologically active substances *viz.* growth regulators, nutrients and trace elements (Kamalam and Rajappan, 1989). Our results confirm the findings of (Chatterjee et al., 2016).

The yield mainly depends upon growth parameters viz., total

Table 1: Germination per cent, seedling vigour index, plant height and lodging score of emmer wheat as influenced by seed priming and planting geometries

Treatments	Germination (%)	SVI	Plant height (cm)				Lodging score (%)
			30 DAS	60 DAS	90 DAS	At harvest	
Main plots:- (Two genotypes with and without seed priming)							
M_1: Gokak local (WOP)	88.73^b	1854.51^c	39.02^a	88.53^a	101.15^a	102.65^a	3.58^a
M_2: Gokak local (WP)	91.34^a	1965.21^{ab}	35.80^b	84.63^{bc}	98.43^{bc}	100.42^b	2.59^b
M_3: DDK 1029 (WOP)	89.02^b	1936.03^b	36.22^b	86.17^b	99.30^b	101.20^b	2.54^b
M_4: DDK 1029 (WP)	92.98^a	2009.16^a	33.87^b	83.78^c	97.47^c	98.45^c	1.95^b
SEm±	1.19	24.64	0.79	1.00	1.51	1.50	0.07
Sub-plots:- (Four planting geometries)							
S_1: 30×15 cm^2	91.60^a	2135.64^a	34.47^b	82.53^b	97.28^b	99.03^a	2.08^c
S_2: 45×15 cm^2	90.77^a	1815.54^c	31.53^b	79.88^b	96.89^b	98.31^a	1.22^d
S_3: 20×20 cm^2	91.30^a	2070.80^b	37.56^{ab}	89.10^a	100.48^{ab}	101.94^a	3.19^b
S_4: 20 cm^2 (RPP)	88.39^b	1742.93^d	41.36^a	91.60^a	101.70^a	103.45^a	4.17^a
SEm±	0.45	1.44	1.47	0.75	0.95	1.61	0.07

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

dry matter production, number of tillers, SPAD value, NDVI value, leaf area, leaf area index, crop growth rate, relative growth rate and leaf area duration in various plant parts such as leaf, stem and reproductive parts of emmer wheat. In present investigation, higher total dry matter production (174.69, 703.62, 1744.91 and 2138.49 g m^{-1} at 30, 60, 90 DAS and at harvest, respectively), number of tillers per meter row length (221.32 and 219.00 at 60 and 90 DAS, respectively), SPAD value (43.66 and 48.85 at 30 and 60 DAS, respectively), NDVI value (0.68, 0.72 and 0.60 at 30, 60 and 90 DAS, respectively), leaf area (36.20, 69.17 and 74.05 dm^2 m^{-1} row length at 30, 60 and 90 DAS, respectively), leaf area index (1.34 and 2.74 at 30 and 60 DAS, respectively), crop growth rate (5.82, 17.63, 34.71 and 13.12 g m^{-2} day^{-1} at 0–30, 30–60, 60–90 DAS and 90-at harvest, respectively), relative growth rate (0.0200 g g^{-1} day^{-1} at 30–60 DAS) and leaf area duration (20.04, 58.24 and 79.23 days at 30, 60 and 90 DAS, respectively) was recorded in primed seed and it was found on par with M_2. While, significantly lower plant growth parameters were recorded in un-primed seeds except plant height, light transmission ratio and lodging score (Table 2, 3, 4 and 5). Leaf area and leaf area index enhance radiant energy

Table 2: Total dry matter production and number of tillers of emmer wheat at various growth stages as influenced by seed priming and planting geometries

Treatments	Total dry matter production (g m^{-2})				No. of tillers m^{-1} rl		
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS
Main plots:- (Two genotypes with and without seed priming)							
M_1: Gokak local (WOP)	153.15^c	617.23^c	1589.15^c	1929.55^c	76.16^a	206.46^b	205.11^b
M_2: Gokak local (WP)	170.09^{ab}	669.97^{ab}	1683.89^b	2059.69^b	79.29^a	212.40^{ab}	209.00^{ab}
M_3: DDK 1029 (WOP)	160.52^{bc}	636.85^{bc}	1625.42^c	1971.52^c	78.61^a	213.64^{ab}	211.00^{ab}
M_4: DDK 1029 (WP)	174.69^a	703.62^a	1744.91^a	2138.49^a	82.90^a	221.32^a	219.00^a
SEm±	2.23	5.01	7.31	11.56	0.74	2.27	2.21
Sub-plots:- (Four planting geometries)							
S_1: 30×15 cm^2	179.93^a	784.46^a	1908.68^a	2367.37^a	89.16^b	242.32^b	240.31^b
S_2: 45×15 cm^2	154.42^b	564.18^c	1474.31^d	1766.12^d	95.14^a	249.29^a	247.05^a
S_3: 20×20 cm^2	166.92^{ab}	691.35^b	1742.85^b	2129.89^b	67.91^c	186.05^c	183.64^c
S_4: 20 cm^2 (RPP)	157.17^b	587.68^c	1517.53^c	1835.87^c	64.75^d	176.16^d	173.11^d
SEm±	3.97	7.43	4.92	6.08	0.21	0.60	0.61

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

Table 3: SPAD and NDVI value of emmer wheat at various growth stages as influenced by seed priming and planting geometries

Treatments	SPAD value			NDVI value		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
Main plots:- (Two genotypes with and without seed priming)						
M_1: Gokak local (WOP)	36.96^b	43.88^b	47.46^a	0.62^c	0.66^b	0.55^b
M_2: Gokak local (WP)	39.98^{ab}	46.82^{ab}	48.22^a	0.66^{ab}	0.71^a	0.59^a
M_3: DDK 1029 (WOP)	41.01^a	46.16^{ab}	48.83^a	0.64^{bc}	0.67^b	0.55^b
M_4: DDK 1029 (WP)	43.66^a	48.85^a	50.41^a	0.68^a	0.72^a	0.60^a
SEm±	1.96	1.04	0.67	0.01	0.01	0.01
Sub-plots:- (Four planting geometries)						
S_1: 30×15 cm^2	45.30^a	51.93^a	52.16^a	0.70^a	0.78^a	0.64^a
S_2: 45×15 cm^2	39.21^{bc}	46.15^b	47.86^{bc}	0.62^b	0.66^b	0.56^{bc}
S_3: 20×20 cm^2	42.43^{ab}	49.70^a	49.80^{ab}	0.68^a	0.74^a	0.60^{ab}
S_4: 20 cm^2 (RPP)	34.67^c	37.93^c	45.09^c	0.59^b	0.57^c	0.49^c
SEm±	1.03	0.83	0.81	0.01	0.01	0.02

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

Table 4: Leaf area, leaf area index and leaf area duration of emmer wheat at various growth stages as influenced by seed priming and planting geometries

Treatments	SPAD value			NDVI value			LAD (days)		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	0-30 DAS	30-60 DAS	60-90 DAS
Main plots:- (Two genotypes with and without seed priming)									
M_1: Gokak local (WOP)	33.38[b]	65.01[c]	70.88[b]	1.23[b]	2.39[a]	2.62[b]	18.31[b]	54.23b	75.19[b]
M_2: Gokak local (WP)	35.28[ab]	67.86[ab]	72.33[b]	1.30[ab]	2.51[a]	2.67[ab]	19.55[ab]	56.96ab	77.46[ab]
M_3: DDK 1029 (WOP)	34.16[b]	66.79[b]	72.12[b]	1.26[ab]	2.47[a]	2.67[ab]	18.86[ab]	55.88ab	77.02[ab]
M_4: DDK 1029 (WP)	36.20[a]	69.17[a]	74.05[a]	1.34[a]	2.56[a]	2.74[a]	20.04[a]	58.24a	79.23[a]
SEm±	0.26	0.50	0.16	0.01	0.02	0.01	0.46	0.86	0.73
Sub-plots:- (Four planting geometries)									
S_1: 30×15 cm^2	43.81[a]	82.17[a]	89.03[a]	1.46[a]	2.74[b]	2.97[b]	21.91[a]	62.99[b]	85.58[b]
S_2: 45×15 cm^2	39.46[b]	77.28[b]	82.41[b]	0.88[c]	1.72[d]	1.83[d]	13.16[c]	38.75[d]	52.98[d]
S_3: 20×20 cm^2	29.67[c]	59.52[c]	65.14[c]	1.48[a]	2.98[a]	3.26[a]	22.29[a]	66.96[a]	93.53[a]
S_4: 20 cm^2 (RPP)	26.09[d]	49.85[d]	52.80[d]	1.30[b]	2.49[c]	2.64[c]	19.41[b]	56.62[c]	76.82[c]
SEm±	0.37	0.58	0.52	0.02	0.02	0.02	0.31	0.67	8.35

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

Table 5: Crop growth rate and relative growth rate of emmer wheat at various growth stages as influenced by seed priming and planting geometries

Treatments	Crop growth rate (g m^{-2} day^{-1})				Relative growth rate (g g^{-1} day^{-1})		
	0-30 DAS	30-60 DAS	60-90 DAS	90 DAS-At hrvst	30-60 DAS	60-90 DAS	90 DAS-At hrvst
Main plots:- (Two genotypes with and without seed priming)							
M_1: Gokak local (WOP)	5.10[b]	15.47[b]	32.40[c]	11.35[b]	0.0201[a]	0.0132[a]	0.0028[a]
M_2: Gokak local (WP)	5.67[a]	16.66[ab]	33.78[ab]	12.53[ab]	0.0198[a]	0.0136[a]	0.0029[a]
M_3: DDK 1029 (WOP)	5.35[b]	15.88[b]	32.95[bc]	11.54[b]	0.0199[a]	0.0134[a]	0.0028[a]
M_4: DDK 1029 (WP)	5.82[a]	17.63[a]	34.71[a]	13.12[a]	0.0200[a]	0.0137[a]	0.0029[a]
SEm±	0.07	0.14	0.25	0.23	0.0001	0.0001	0.0001
Sub-plots:- (Four planting geometries)							
S_1: 30×15 cm^2	6.00[a]	20.15[a]	37.47[a]	15.29[a]	0.0213[a]	0.0139[a]	0.0031[a]
S_2: 45×15 cm^2	5.15[b]	13.66[c]	30.34[c]	9.73[d]	0.0188[b]	0.0129[b]	0.0026[c]
S_3: 20×20 cm^2	5.56[ab]	17.48[b]	35.03[b]	12.90[b]	0.0206[a]	0.0137[ab]	0.0029[b]
S_4: 20 cm^2 (RPP)	5.24[b]	14.35[c]	31.00[c]	10.61[c]	0.0191[b]	0.0134[ab]	0.0028[b]
SEm±	0.13	0.23	0.25	0.11	0.0003	0.0003	0.0001

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

absorption, promoting efficient conversion into chemical energy. This accelerates dry matter accumulation in plant parts, facilitates quick germination by converting complex seed foods into simple sugars and supports rapid seedling emergence and establishment by reducing competition. The effects of seed treatment with an organic formulation are attributed to physiologically active substances in cow urine, including growth regulators, nutrients and trace elements (Kamalam and Rajappan, 1989).

Primed seeds recorded significantly higher light interception ratio (68.67, 77.89 and 81.99) and lower light transmission ratio (35.92, 13.78 and 12.95) at 30, 60 and 90 DAS, respectively as compared to un-primed seeds (Table 6). These might be due to uniform germination, early canopy

Table 6: Light interception ratio and light transmission ratio of emmer wheat at various growth stages as influenced by seed priming and planting geometries

Treatments	Light interception ratio (LIR)			Light transmission ratio (LTR)		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
Main plots:- (Two genotypes with and without seed priming)						
M_1: Gokak local (WOP)	65.96^{ab}	76.56^{ab}	81.14^{a}	39.54^{a}	21.13^{a}	19.55^{a}
M_2: Gokak local (WP)	69.10^{a}	78.75^{a}	82.65^{a}	36.92^{b}	15.33^{a}	15.65^{a}
M_3: DDK 1029 (WOP)	64.87^{b}	75.98^{b}	80.35^{a}	38.89^{a}	19.35^{a}	18.25^{a}
M_4: DDK 1029 (WP)	68.67^{a}	77.89^{a}	81.99^{a}	35.92^{b}	13.78^{a}	12.95^{a}
SEm±	1.12	1.29	1.36	0.66	0.27	0.25
Sub-plots:- (Four planting geometries)						
S_1: 30×15 cm^2	71.99^{b}	86.56^{b}	89.71^{b}	26.28^{c}	12.77^{c}	13.43^{c}
S_2: 45×15 cm^2	75.94^{a}	89.42^{a}	93.00^{a}	25.85^{c}	11.00^{d}	10.10^{d}
S_3: 20×20 cm^2	66.43^{c}	72.80^{c}	77.72^{c}	43.61^{b}	17.61^{b}	16.40^{b}
S_4: 20 cm^2 (RPP)	54.24^{d}	60.40^{d}	65.71^{d}	55.52^{a}	28.20^{a}	26.48^{a}
SEm±	0.59	0.69	0.72	0.36	0.19	0.19

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

establishment, increased leaf area, stress tolerance, nutrient uptake and overall plant health, seed priming with organic formulations enhances the Light Interception Ratio in wheat. This improved LIR contributes to higher photosynthesis rates, increased biomass accumulation and ultimately, enhanced grain yields in emmer wheat crops. These results are in agreement with (Reddy et al., 2003).

3.1.2. Yield and yield attributes of emmer wheat as influenced by seed priming

The observed increase in yield among the primed seed was mainly due to the higher yield attributes recorded in primed seed viz., thousand grain weight (40.71 g), grain weight spike^{-1} (2.64 g), grain yield (3853 kg ha^{-1}), straw yield (6426 kg ha^{-1}) and numerically higher harvest index (37.27%) than un-primed seeds (38.61 g, 2.26 g, 3278 kg ha^{-1}, 5888 kg ha^{-1} and 35.62%, respectively) (Table 7). 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

Table 7: Yield and yield attributes of emmer wheat as influenced by seed priming and planting geometries

Treatment	Grain weight spike^{-1} (g)	Test weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	HI (%)
Main plots:- (Two genotypes with and without seed priming)					
M_1: Gokak local (WOP)	2.26^{b}	38.61^{b}	3278^{b}	5888^{b}	35.62^{a}
M_2: Gokak local (WP)	2.45^{ab}	40.41^{ab}	3615^{ab}	6109^{b}	36.91^{a}
M_3: DDK 1029 (WOP)	2.37^{ab}	38.79^{ab}	3501^{ab}	6142^{b}	36.03^{a}
M_4: DDK 1029 (WP)	2.64^{a}	40.71^{a}	3853^{a}	6426^{a}	37.27^{a}
SEm±	0.06	1.54	1.46	0.89	0.97
Sub-plots:- (Four planting geometries)					
S_1: 30×15 cm^2	2.59^{a}	41.67^{a}	4020^{a}	6630^{a}	37.49^{a}
S_2: 45×15 cm^2	2.74^{a}	42.41^{a}	3408^{b}	6006^{bc}	35.88^{a}
S_3: 20×20 cm^2	2.32^{b}	38.53^{ab}	3674^{ab}	6178^{b}	37.17^{a}
S_4: 20 cm^2 (RPP)	2.06^{c}	35.91^{b}	3145^{c}	5752^{c}	35.29^{a}
SEm±	0.05	0.93	1.80	0.61	1.18

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

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).

3.1.3. Economics of emmer wheat as influenced by seed priming

Significant differences were observed in gross returns, net returns and benefit-cost ratio of emmer wheat with respect to with and without seed priming. Primed seeds recorded significantly higher gross returns (Rs. 1,41,915 ha^{-1}), net returns (₹ 92,033 ha^{-1}) and benefit-cost ratio (2.88). Whereas, significantly lowest gross returns (₹ 1,21,192 ha^{-1}), net returns (₹ 72,792 ha^{-1}) and benefit-cost ratio (2.53) was recorded with respect to un-primed seeds (Table 8). These might be due to higher grain yield and straw yield was recorded in primed seeds as compared to un-primed seeds. The results corroborated the finding of (Kumar et al., 2015).

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

Treatment	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B:C ratio
Main plots:- (Two genotypes with and without seed priming)			
M_1: Gokak local (WOP)	121192[b]	72792[b]	2.53[b]
M_2: Gokak local (WP)	133253[ab]	84231[ab]	2.76[ab]
M_3: DDK 1029 (WOP)	129284[ab]	80773[ab]	2.70[ab]
M_4: DDK 1029 (WP)	141915[a]	92033[a]	2.88[a]
SEm±	2215	1382	0.05
Sub-plots:- (Four planting geometries)			
S_1: 30×15 cm^2	147989[a]	101742[a]	3.20[a]
S_2: 45×15 cm^2	125890[c]	80056[c]	2.75[c]
S_3: 20×20 cm^2	135377[b]	88215[b]	2.87[b]
S_4: 20 cm^2 (RPP)	116388[d]	59816[d]	2.06[d]
SEm±	1121	713	0.02

1 US$= INR 82.59 (average monthly of February'2023); Mean followed by the same letter(s) did not differ significantly by DMRT (p= 0.05)

3.2. Influence of planting geometries on growth, yield and yield attributes and economics of emmer wheat

3.2.1. Growth parameters of emmer wheat as influenced by different planting geometries

The germination percentage of emmer wheat did not significantly influence on the different planting geometries. 30×15 cm^2 planting geometry recorded significantly higher seedling vigour index (2135.64) (Table 1). This could potentially result from improved vegetative growth and the development of roots in the deeper layer of the soil profile. Similar results were recorded by Kanakadurga (2012).

Significantly lower plant height was recorded in 45×15 cm^2 planting geometry (31.53, 79.88 and 96.89 cm^2), lodging score (1.22%), higher number of tillers (95.14, 249.29 and 247.05), light interception ratio (75.94, 89.42 and 93.00) and lower light transmission ratio (25.85, 11.00 and 10.10) at 30, 60 and 90 DAS, respectively and it was on par with 30×15 cm^2 planting geometry as compared to other planting geometries (Table 1, 2 and 6). This might be due to wider spacing decreased competition among plants for light, water, space and nutrients due to higher light interception, root distribution and nutrient availability that play important role in plant growth. The obtained results were in similarity with those of (Chatterjee et al., 2016) and (Thapa et al., 2011), who also observed decreased plant height in wider planting geometries as compared to narrow planting geometries.

The planting geometry of 30×15 cm^2 recorded significantly higher total dry matter production (179.93, 784.46, 1908.68 and 2367.37 g m^{-1}), SPAD value (45.30, 51.93 and 52.16), NDVI value (0.70, 0.78 and 0.64), leaf area (43.81, 82.17 and 89.03 dm^2 m^{-1} row length), leaf area index (1.46, 2.74 and 2.97), leaf area duration (21.91, 62.99 and 85.58 days), crop growth rate (6.00, 20.15, 37.47 and 15.29 g m^{-2} day^{-1}) and relative growth rate (0.0213, 0.0139 and 0.0031 gg^{-1} day^{-1}) at 30, 60, 90 and at harvest, respectively and it was on par with 20×20 cm^2 planting geometry as compared to other planting geometries (Table 2, 3, 4 and 5). This might be due to system of wheat intensification had higher tillers m^{-2} and leaf area index indicating higher photosynthetic efficiency which in turn resulted in higher dry matter accumulation. Higher dry matter production of rice was recorded under system of rice intensification as compared to conventional method (Thakur et al., 2010). Similar type of results was recorded by (Singh et al., 2015) under system of rice intensification. Chatterjee et al. (2016) reported that, system of wheat intensification recorded significantly higher dry matter accumulation when compared to conventional method. System of finger millet intensification recorded higher dry matter production as compared to conventional practice (Natarajan et al., 2019).

3.2.2. Yield and yield attributes of emmer wheat as influenced by different planting geometries

Significantly difference in grain weight per spike, thousand grain weight, grain and straw yields were observed among different planting geometries. 30×15 cm^2 planting geometry recorded significantly higher grain weight per spike (2.59 g), thousand grain weight (41.67 g), grain yield (4020 kg ha^{-1}), straw yield (6630 kg ha^{-1}) and numerically higher harvest index (37.49%) and it was on par with 20×20 cm^2 and 45×15 cm^2 planting geometry in some respective parameters only. While, significantly lower grain weight (2.06 g $spike^{-1}$), thousand grain weight (35.91 g), grain yield (3145 kg ha^{-1}), straw yield (5752 kg ha^{-1}) and harvest index (35.29%) was recorded in 20 cm row spacing treatment (Table 7). These might be due to wider spacing facilitated better utilization of resources for plant under SWI techniques. Wider spacing's reduced competition between plants for water, nutrient, light and space that lead better growth of plants and yield and yield attributes i.e. higher grain weight per spike. In the experiment system of wheat intensification (SWI) recorded significantly higher number of tillers per plant, number of effective tillers per plant, number of grains per spike, number of spike, spike length, test weight and productivity as compared to farmer practices (Khadka and Raut, 2011) and (Hussain et al., 2012).

3.2.3. Economics of emmer wheat as influenced by different planting geometries

Economic returns of emmer wheat differed significantly among planting geometries. 30×15 cm^2 planting geometry recorded significantly higher gross returns (₹ 1,47,989 ha^{-1}), net returns (₹ 1,01,742 ha^{-1}) and benefit-cost ratio (3.20). While, significantly lower gross returns (₹ 1,16,388 ha^{-1}), net returns (₹ 59,816 ha^{-1}) and benefit-cost ratio (2.06) was recorded in 20 cm planting geometry (Table 8). These might be due to higher grain and straw yields was recorded in moderately closer planting geometry as compared to conventional practices. Rivalled that seed treated plots followed by 10×10 cm^2 spacing wheat sown recorded significantly higher gross returns, net returns and B:C ratio as compared to conventional method of wheat cultivation Kumar et al. (2015).

4. Conclusion

Raising of emmer wheat under System of Wheat Intensification with moderately closer spacing of 30×15 cm^2 and seed priming with organic solution optimized growth, yield and yield attributes of emmer wheat viz., number of tillers, spike length, spike weight, number of grains per spike, thousand grain weight, grain and straw yields, through efficient utilization of space, nutrients, light and moisture. Adaption of System of Wheat Intensification can reduce the seed requirement by 70 to 75%.

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