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Effect of Weather and Accumulated Weather Parameters on Yield of Finger Millet Grown in Different Planting Geometry, Methods of Establishment and Nutrient Sources

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Authors' contributions

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

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ABSTRACT

Environment is a basic and fundamental factor determining the growth of plants. Amount and distribution of rainfall is the key variable influencing crop productivity in rainfed farming. Maximum heat units of 1386 growing degree days, rainfall (577 mm), rainy days (33), PET (456 mm), SSH (677 hrs.), day length (1474 hrs.), photo thermal units (16921) and helio thermal units (7372) were recorded during 2015 compared to growing season 2016 with growing degree days (GDD) (1266), rainfall (102 mm), rainy days (9), PET (382 mm), SSH (701 hrs.), day length (1474 hrs.), photo thermal units (15136) and helio thermal units (8163). Increased cumulative SSH and helio thermal units during 2016 was mainly due to clear weather condition and higher maximum and minimum temperature at crop growing period. Higher grain yield, straw yield, heat, photo thermal and helio thermal use efficiency (3638 and 2443 kg ha^{-1}, 2.62, 0.22 and 0.49 during 2015, 1.93, 0.16 and

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0.30 during 2016, respectively) was recorded in transplanting with recommended spacing along with application of RDF (50:40:37.5 NPK, ha^{-1}) + FYM 7.5 t ha^{-1} compared to other treatment combinations.

Keywords: Weather parameters; finger millet cultivation.

1. INTRODUCTION

Finger millet (*Eleusine coracana* (L.) Gaertn.) is a staple food for working class and also an ideal food for people suffering from diabetes, cardiac and blood pressure issues considering its higher dietary fiber. Finger milletis one of the important millets which occupies the highest area under cultivation among the small millets and a predominant food crop of Southern Karnataka, mainly grown under rainfed conditions. Realizing higher yield of finger millet needs the adoption of new high yielding, fertilizer responsive varieties with proper rain water conservation and nutrient management practices.

The productivity is low due to late transplanting, faulty methods of cultivation and little or no use of fertilizers. More importantly, its greater plasticity for adaptability to different ecological condition, feasibility for transplanting, better suitability to different cropping systems and mid-season correction during vagaries of monsoon in the contingent plans made it popular in Southern Karanataka (Krishne Gowda, 2004).

Some of practices like right time for sowing during *Kharif*, method of crop establishment, weed management, nutrient management and cropping system practice have contributed for sustainable productivity of finger millet under dry land conditions [1].

2. MATERIALS AND METHODS

A field experiments were carried out to study the “Effect of planting geometry, methods of establishment and nutrient sources on growth and yield of finger millet (*Eleusine coracana* L.)”during *Kharif* season of 2015 and 2016 under rainfed conditions. *Kharif* crops, are also known as monsoon crops, are the crops which are grown during the monsoon or rainy season (June to October). The soil of experimental site was slightly acidic in reaction (5.70), the soil was low in available nitrogen (213.24 kg ha^{-1}), medium in available phosphorous (26.50 kg ha^{-1}) and low in potassium (113.48 kg ha^{-1}). The organic carbon content was medium (0.45 g kg^{-1} or %).

The experiment was laid out in Randomized Complete Block *Design* (RCBD) with factorial concept and replicated thrice. The treatment comprised of three factors, first factor was Methods of establishment (M_1: Direct sowing and M_2: Transplanting), second factor was planting geometry (S_1: Recommended spacing 30×10 cm, S_2: 30 × 30 cm and S_3: 45×30 cm and third factor was nutrient sources (N_1: Recommended dose of FYM at 7.5 t ha^{-1} + RDF (50:40:37.5 kg NPK ha^{-1}) and N_2: FYM on equivalent basis + FYM at 7.5 t ha^{-1}).

2.1 Accumulated Weather Parameters are Calculated with Following Formulas

2.1.1 Growing degree days (GDD)

Growing degree days at different phenological stages were calculated by summation of daily mean temperature above base temperature for a corresponding period from sowing as suggested by Monteith [2].

$$GDD = \sum \frac{(T\ max + T\ min)}{2} - T\ base$$

Where,

T max and T min are maximum, minimum temperature.
T base is base temperature was taken as 12^0 C.

2.1.2 Helio thermal units (HTU)

Helio thermal unit was calculated using the formula given by Rajput [3].

HTU = GDD x Cumulative Sunshine Hours (from sowing to physiological maturity)

2.1.3 Photo thermal units (PTU)

The photo thermal unit was calculated as a product of growing degree days (GDD) to the day length as given by Wilsie [4].

PTU= GDD x Day length

2.1.4 Heat use efficiency (HUE)

The heat use efficiency was worked out as the ratio of grain yield to the GDD [5].

$$HUE= \frac{\text{Total dry matter (Grain yield kg ha}^{-1}\text{)}}{\text{GDD}}$$

2.1.5 Photo thermal use efficiency (PTUE)

The photo thermal use efficiency was worked out as the ratio of grain yield to the photo thermal units given by Wang [6].

$$PTUE= \frac{\text{Total dry matter (Grain yield kg ha}^{-1}\text{)}}{\text{PTU}}$$

2.1.6 Helio-thermal use efficiency (HTUE)

The Helio thermal use efficiency was calculated by as the ratio of grain yield to the heat use efficiency given by Rajput [3].

HTUE (kg/HTU)= Total dry matter (Grain yield kg ha^{-1}) / HTU

3. RESULTS AND DISCUSSION

3.1 Effect of Weather Data

Environment is a basic and fundamental factor determining the growth of plants and regarded as foster parent of plants. Thus, the fluctuations in weather conditions directly affect the crop growth and development and finally the expected yield. Rainfall, amount and distribution, is the key variable influencing crop productivity in rainfed farming. Intermittent and prolonged droughts are major causes of yield reduction in most of the crops.

Long term data for India, indicated that rainfed areas experience 3-4 drought years in every 10-year period. Of these, two to three are in moderate and one or two may be of severe intensity. So for no definite trend has been identified as a specific climate change fingerprint [7,8]. reported that Karnataka ranks first in the country with more than 40% of its total dryland area under finger millet cultivation and accounting for more than 50% production in the country. Agrometerological conditions cause wide fluctuations on growth, development and yield of finger millet.

Eghball et al. [9] reported that the management practices may in some cases reduce temporal variability but in other cases it will have little effect on the year to year variability of crop yields. The year to year fluctuation is primarily a result of variable weather conditions that prevail in a given agroclimatic situation. In this context, the weather conditions prevailed during the period of experimentation would definitely have a direct bearing on the potentiality of any crop in general and finger millet in particular. The crop experienced weather conditions during the crop growth period as indicated by the climatic data are given in Tables 1 and 2.

The weather parameters such as rainfall, maximum and minimum temperatures, mean relative humidity, mean sunshine hours, wind speed and pan evaporation values were conducive to the crop during the growth period of *Kharif*-2015 and during *Kharif*-2016 not conducive because of low rainfall and there was no incidence of any major pest or disease outbreak during the growth period in both the years.

The actual total rainfall received during the crop growth period during 2015 (August to December) and 2016 (August to November) was 576.6 mm and 101.8 mm, respectively. The rainfall during 2015 was 159.9 mm higher than normal whereas, 2016 recorded 225.1 mm lower rainfall than the normal. During crop growth period of 2015, August (71.0 mm), October (80.8 mm) and December (4.2 mm) months have recorded less rainfall compared to normal rainfall (134.3 mm, 167.9 mm and 11.7 mm, respectively), whereas, September (254.6 mm) and November (180.4 mm) months have recorded higher rainfall than the normal (194.9 mm and 53.5 mm, respectively). During *Kharif*-2016, crop growing period (August: 27.20 mm, September: 44.40 mm, October: 30.20 mm and November: 0.0 mm) recorded lower rainfall compared to normal rainfall (130.4 mm, 197.4 mm, 165.5 mm and 58.5 mm, respectively).

Kharif-2015 received good rainfall during the last week of August and first week of September (254.6 mm) which has influenced on tillering capacity resulting in growth of finger millet due to sufficient moisture. November month also received the higher rainfall (180.4 mm) during reproductive stage with sufficient moisture and resulted in higher yield and yield attributing parameters in finger millet. One dry spell of 25 days occurred during the 8^{th} October to 1^{st} November, and it was managed with one protective irrigation of 2.00 mm in hose pipe from a tanker using farm pond water.

Nutrient supplies through fertilizer or organic sources contributed enormously to boost the production and productivity of crops across the country. However, it was clear from the result that during 2016 application of nutrients has not substantially increased the yield. For the efficient use of applied fertilizers adequate quantity of soil moisture is of paramount importance which was inadequate during crop growth period 2016. In *Kharif*-2016, since from germination/transplanting to harvest of crop, severe drought was prevailed. Since crop was grown under the rainfed conditions severe drought affected the crop growth and development. Drought occurred during 18th August to 4th September (15 days), 16th September to 28th September (13 days), 30th September to 9th October (10 days) and 14th October to 2nd December (49 days). Total 87 days of severe drought has occurred. This drought was managed with protective irrigation of harvested farm pond water at critical stage of crop growth. The severe drought affected on crop growth due to severe moisture stress as evidenced by the sharp decrease in the grain yield during 2016 compared to 2015 due to lower crop growth and yield parameters.

During 2015, both maximum and minimum temperature was warmer compared to normal during the crop growth period, whereas November month recorded lower maximum temperature compared to normal. The mean relative humidity, mean sunshine hours, mean wind speed and pan evaporation recorded had minor variations compared to normal, but November had recorded 7% higher relative humidity, 2.9 hrs. day^{-1} of lesser sunshine hours and 1.7 mm day^{-1} lesser pan evaporation which has helped to maintain soil moisture in the root zone during crop reproductive stage and helped for better grain filling and higher yield.

During 2016, with regard to maximum and minimum temperature, mean relative humidity, mean sunshine hours, mean wind speed, and pan evaporation, there was not much deviation during crop growth period, but during October and November months higher maximum temperature (1.8 and 2.9˚C, respectively), higher sunshine hours (1.9 and 2.3 hrs. day^{-1}) coupled with higher pan evaporation (0.2 and 0.1 mm day^{-1}) has drastically reduced finger millet yield compared to first year of study.

3.2 Accumulated Weather Parameters

Three climatic parameters *viz.*, temperature, rainfall and light are more important for optimum crop growth and development for exploiting the potentiality of a crop. Among these, temperature plays a vital role in almost all biological processes of crop plants. It is one of the most important climatic factors affecting the growth, development and yield of crops. Influence of different weather parameters on growth and yield of finger millet has been studied through accumulated weather parameters (Tables 3 to 4).

The growing degree day (GDD) is a temperature derived index used to correlate with the amount of heat available for the growth of plants. Temperature is a key factor for the timing of biological processes and hence the growth and development of living biota. All the physical and physiological processes are temperature dependent. The heat unit system or growing degree days (GDDs) assumes that in general there is a direct and linear relationship between growth of plant and temperature. The amount of heat energy an organism accumulates over a period of time is often expressed as a “growing degree-day” (GDD). The growth rate of many organisms is controlled by temperature. GDDs are used to relate plant growth, development, and maturity to air temperature.

At 30 DAS, maximum accumulated GDD (390) was observed with higher SSH (242 hrs.) and day length (384 hrs.) compared to later crop growth stages viz., 30 to 60 DAS (354, 128 and 363 hrs. GDD, SSH and day length, respectively) followed by 60 to 90 DAS (373, 223 and 361 hrs., respectively) and 90 DAS to harvest (270, 84 and 366 hrs., respectively). Maximum GDD was mainly due to higher SSH and day length hours during respective crop growth stage. During the crop growing period sufficient rainfall was received at 30 to 60 DAS (200 mm with 9 rainy days) followed by sowing to 30 DAS (192 mm with 11 rainy days), 60 to 90 DAS (101 mm with 5 rainy days) and 90 DAS to harvest (84 mm with 8 rainy days).

Photo thermal and Helio thermal units differed with different growth stages, however, maximum photo thermal units was recorded upto 30 days (4827) followed by 60 to 90 DAS (4346), 30 to 60 DAS (4271) and minimum photo thermal units was observed at 90 DAS to harvest (3477). Similar kind of observation was noticed with helio thermal units. Maximum was recorded at 60 to 90 DAS (2742) followed by 0 to 30 DAS (2272), 30-60 DAS (1520) and minimum helio thermal units were recorded at 90 DAS to harvest (837).

Table 1. Meteorological data of the experimental area during 2015 at GKVK, Bengaluru, India

Year/ Months	Rainfall (mm)			Mean temperature (ºC)						Mean Relative Humidity (%)			Mean Sunshine hours (hr day^{-1})			Mean wind speed (km hr^{-1})			Pan evaporation (mm day^{-1})		
				Maximum			Minimum														
	N	**A**	**D**	**N**	**A**	**D**	**N**	**A**	**D**	**N**	**A**	**D**	**N**	**A**	**D**	**N**	**A**	**D**	**N**	**A**	**D**
August	134.3	71.0	-63.3	27.6	29.3	1.7	18.9	19.6	0.7	89.0	92.0	3.0	4.7	5.7	1.0	10.5	8.3	-2.2	4.9	3.8	-1.1
September	194.9	254.6	59.7	28.1	28.7	0.6	18.8	19.2	0.4	88.9	91.0	2.1	5.8	5.5	-0.3	7.1	6.0	-1.1	5.1	4.0	-1.1
October	167.9	80.8	-87.1	27.8	29.3	1.5	18.3	19.1	0.8	88.0	89.0	1.0	6.0	6.6	0.6	5.6	5.8	0.2	4.7	4.5	-0.2
November	53.5	180.4	126.9	26.7	25.3	-1.4	16.6	17.9	1.3	87.0	94.0	7.0	6.2	3.3	-2.9	6.1	7.2	1.1	4.5	2.8	-1.7
December	11.7	4.2	-7.5	26.2	27.6	1.4	14.5	19.9	5.4	86.7	91.0	4.3	7.3	6.5	-0.8	7.0	6.4	-0.6	4.6	3.4	-1.2
Total/Mean	**562.3**	**591.0**	**28.7**	**27.28**	**28.04**	**0.8**	**17.4**	**19.1**	**1.7**	**87.9**	**91.4**	**3.5**	**6.0**	**5.5**	**-0.5**	**7.3**	**6.7**	**-0.6**	**4.7**	**3.7**	**-1.0**

Table 2. Meteorological data of the experimental area during 2016 at GKVK, Bengaluru, India

Year/ Months	Rainfall (mm)			Mean temperature (ºC)						Mean relative humidity (%)			Mean sunshine hours (hr. day^{-1})			Mean wind speed (km hr^{-1})			Pan evaporation (mm day^{-1})		
				Maximum			Minimum														
	N	**A**	**D**	**N**	**A**	**D**	**N**	**A**	**D**	**N**	**A**	**D**	**N**	**A**	**D**	**N**	**A**	**D**	**N**	**A**	**D**
August	130.4	27.2	-103.2	27.6	28.1	0.5	18.9	19.5	0.6	89.0	92.0	3.0	4.7	5.7	1.0	10.4	9.2	-1.2	4.8	4.0	-0.8
September	197.4	44.4	-153.0	28.0	27.8	-0.2	18.8	19.0	0.2	88.9	92.0	3.1	5.7	3.5	-2.2	7.1	7.0	-0.1	5.0	3.4	-1.6
October	165.5	30.2	-135.3	27.8	29.6	1.8	18.2	18.0	-0.2	88.0	85.0	-3.0	6.0	7.9	1.9	5.5	4.6	-0.9	4.7	4.9	0.2
November	58.5	0.0	-58.5	26.7	29.6	2.9	16.5	16.2	-0.3	84.7	82.0	-2.7	6.2	8.5	2.3	6.1	6.2	0.1	4.5	4.6	0.1
December	11.9	63.5	51.6	26.2	27.2	1.0	14.5	14.7	0.2	84.4	85.0	0.6	7.2	6.9	-0.3	6.9	6.4	-0.5	4.5	3.9	-0.6
Total/Mean	**563.7**	**165.3**	**-398.4**	**27.3**	**28.5**	**1.2**	**17.4**	**17.5**	**0.1**	**87.0**	**87.2**	**0.2**	**6.0**	**6.5**	**0.5**	**7.2**	**6.7**	**-0.5**	**4.7**	**4.2**	**-0.5**

Note: N- Normal meteorological data (mean of 1976 – 2015), A - Actual meteorological data, D - Deviation from the normal (A-N)

Table 3. Grain yield, straw yield and harvest index as influenced by planting geometry, methods of establishment and nutrient sources in finger millet

Treatments	Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})			Harvest index		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Method of establishment									
M_1 = Direct sowing (spot placement)	3034	1974	2504	5369	3797	4583	0.361	0.341	0.351
M_2= Transplanting	3240	2102	2671	5592	3899	4745	0.367	0.351	0.359
S. Em. ±	45	95	51	65	136	75	0.004	0.012	0.006
C. D.@ 5%	133	NS	147	191	NS	NS	NS	NS	NS
Planting geometry									
S_1= Recommended spacing 30 cm × 10 cm	3250	2224	2737	5543	4154	4849	0.369	0.347	0.358
S_2=30 cm × 30 cm	3111	2103	2607	5462	3872	4667	0.363	0.353	0.358
S_3=45 cm × 30 cm	3051	1788	2419	5436	3518	4477	0.359	0.339	0.349
S. Em. ±	55	116	63	79	166	91	0.006	0.014	0.008
C. D.@ 5%	NS	341	180	NS	489	261	NS	NS	NS
Nutrient source									
N_1= Recommended dose (FYM at 7.5 t ha^{-1} + RDF 50:40:37.5 kg NPK ha^{-1})	3223	2178	2701	5581	4221	4901	0.366	0.342	0.354
N_2= FYM at 7.5 t ha^{-1} + FYM on N equivalent basis	3051	1898	2475	5381	3475	4428	0.362	0.351	0.356
S. Em. ±	45	95	51	65	136	75	0.004	0.012	0.006
C. D.@ 5%	133	278	147	191	399	213	NS	NS	NS
Method of establishment × Planting geometry (M × S)									
S. Em. ±	78	164	89	112	235	130	0.008	0.020	0.011
C. D.@5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Method of establishment ×nutrient source (M ×N)									
S. Em. ±	64	134	73	92	192	106	0.006	0.017	0.009
C. D.@ 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Planting geometry × nutrient source (S ×N)									
S. Em. ±	78	164	89	112	235	130	0.008	0.020	0.011
C. D.@ 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Method of establishment×Planting geometry×Nutrient source (M ×S ×N)									
S. Em. ±	111	232	127	159	333	183	0.011	0.029	0.015
C. D.@ 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4. Growing degree days, rainfall (mm), rainy days, potential evapotranspiration, sunshine hours, day length (Hrs.), photo thermal units and helio thermal units

Stages (days)	Dates of sowing		Number of days		Growing degree days		Rainfall (mm)		Rainy days	
	2015 (10/8/2015)	2016 (10/8/2016)	2015	2016	2015	2016	2015	2016	2015	2016
30	10/9/2015	10/9/2016	32	32	390	365	192	39	11	4
60	10/10/2015	10/10/2016	30	30	354	355	200	33	9	3
90	10/11/2015	10/11/2016	31	31	373	356	101	30	5	2
harvest	12/12/2015	26/11/2016	32	16	270	189	84	0	8	0
Total			**125**	**109**	**1386**	**1266**	**577**	**102**	**33**	**9**
Stages	**PET (mm)**		**SSH (Hrs.)**		**Day length (hrs.)**		**Photo thermal units**		**Helio thermal units**	
	2015	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**
30	120	108	242	163	384	384	4827	4527	2272	1961
60	117	101	128	145	362	362	4271	4293	1520	1775
90	141	109	223	251	361	361	4346	4154	2742	2878
harvest	78	64	84	142	366	366	3477	2160	837	1550
Total	**456**	**382**	**677**	**701**	**1474**	**1474**	**16921**	**15136**	**7372**	**8163**

Potential evapotranspiration was higher at 0 to 30 DAS (120 mm), 30 to 60 DAS (117 mm), 60 to 90 DAS (141 mm) and the lowest was recorded at 90 to harvest (78 mm). Higher PET was mainly due to higher SSH and day length hours.

During 2016, maximum cumulative GDD (365) was observed at 0-30 DAS with maximum SSH (163 hrs.) and day length (384 hrs.) compared to later crop growth stages viz., 30 to 60 DAS (355, 145 and 363 hrs., respectively) followed by 60 to 90 DAS (356, 251 and 361 hrs., respectively) and 90 DAS to harvest (189, 142 and 366 hrs., respectively). Higher GDD was mainly due to higher SSH and day length hours during respective crop growth stages. During the crop growing period, ample of rainfall with minimum rainy days was recorded at 0 to 30 DAS (39 mm with 4 rainy days), 30 to 60 DAS (33 mm with 3 rainy days), 60 to 90 DAS (30 mm with 2 rainy days) and no rain was recorded at 90 DAS to harvest.

Photo thermal and helio thermal units differed at different growth stages, however, maximum photo thermal units was recorded upto 30 days (4527) followed by 60 to 90 DAS (4293), 30 to 60 DAS (4154) and minimum photo thermal was observed at 90 DAS to harvest (2160). Similar kind of observation was noticed with helio thermal units. Maximum was recorded at 60 to 90 DAS (2878) followed 0 to 30 DAS (1961), 30-60 DAS (1775) and minimum helio thermal units was recorded at 90 DAS to harvest (1550). Potential evapotranspiration was maximum at 0 to 30 DAS (108 mm), 30 to 60 DAS (101 mm), 60 to 90 DAS (109 mm) and the lowest was recorded at 90 DAS to harvest (64 mm) during 2016. Higher PET was mainly due to higher SSH and day-length hours.

In general, between the seasons, total maximum heat units of 1386 growing degree days, rainfall (577 mm), rainy days (33), PET (456 mm), SSH (677 hrs.), day length (1474 hrs.), photo thermal units (16921) and helio thermal units (7372) were recorded during 2015 compared to growing season 2016 with growing degree days (1266), rainfall (102 mm), rainy days (9), PET (382 mm), SSH (701 hrs.), day length (1474 hrs.), photo thermal units (15136) and helio thermal units (8163). Increased cumulative SSH and helio thermal units during 2016 was mainly due to clear weather condition and higher maximum and minimum temperature at crop growing period.

Due to deficit rainfall with maximum PET levels crop suffered with moisture stress and total crop duration was reduced to 109 days instead of 120 days. These meteorological parameters directly influenced the finger millet yield.

3.3 Accumulated Weather Parameters Based on Grain Yield, Photo Thermal and Helio Thermal Efficiencies

Higher accumulated weather parameter use efficiency was noticed in *Kharif*-2015 compared to *Kharif*-2016, due to higher grain yield of finger millet (Table 5).

Table 5. Grain yield, heat use efficiency, photo thermal use efficiency and helio thermal use efficiency as influenced by weather parameters

Treatments	Grain yield (kg ha^{-1})		Heat use efficiency (kg ha^{-1} per O^{o} C day)		Photo thermal use efficiency		Helio thermal use efficiency	
	2015	2016	2015	2016	2015	2016	2015	2016
$M_1S_1N_1$	3150	2421	2.27	1.91	0.19	0.16	0.43	0.30
$M_1S_1N_2$	3090	2194	2.23	1.73	0.18	0.14	0.42	0.27
$M_1S_2N_1$	3085	2112	2.23	1.67	0.18	0.14	0.42	0.26
$M_1S_2N_2$	2985	1785	2.15	1.41	0.18	0.12	0.40	0.22
$M_1S_3N_1$	2994	1691	2.16	1.34	0.18	0.11	0.41	0.21
$M_1S_3N_2$	2904	1645	2.10	1.30	0.17	0.11	0.39	0.20
$M_2S_1N_1$	3638	2443	2.62	1.93	0.22	0.16	0.49	0.30
$M_2S_1N_2$	3123	1839	2.25	1.45	0.18	0.12	0.42	0.23
$M_2S_2N_1$	3265	2321	2.36	1.83	0.19	0.15	0.44	0.28
$M_2S_2N_2$	3110	2196	2.24	1.73	0.18	0.15	0.42	0.27
$M_2S_3N_1$	3211	2084	2.32	1.65	0.19	0.14	0.44	0.26
$M_2S_3N_2$	3096	1733	2.23	1.37	0.18	0.11	0.42	0.21

M1, M2 = direct sowing/ transplanting;
S1, S2, S3 = Planting spacings = 30 cm x 10 cm, 30 cm x 30 cm, 45 cm x 10 cm;
N1, N2 = Nutrient sources

However, maximum heat, photo thermal and helio thermal use efficiency (2.62, 0.22 and 0.49 during 2015, 1.93, 0.16 and 0.30 during 2016, respectively) was recorded in transplanting with recommended spacing along with application of RDF (50:40:37.5 NPK, ha^{-1}) + FYM 7.5 t ha^{-1} compared to other treatment combinations. Comparatively lower heat, photo thermal and helio thermal use efficiency (2.10, 0.17 and 0.39 during 2015, 1.30, 0.11 and 0.20 during 2016, respectively) was observed in direct sowing method with wider spacing(45×30 cm spacing) along with application of FYM @ 7.5 t ha^{-1} + FYM on N equivalent basis.

4. CONCLUSION

Higher grain yield, straw yield, heat, photo thermal and helio thermal use efficiency (3638 and 2443 kg ha $^{-1}$, 2.62, 0.22 and 0.49 during 2015, 1.93, 0.16 and 0.30 during 2016, respectively) was recorded in transplanting with recommended spacing along with application of RDF (50:40:37.5 NPK, ha^{-1}) +FYM 7.5 t ha^{-1} compared to other treatment combinations.

NOTE

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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