Assessing the Water and Thermal Use Efficiencies of Groundnut (*Arachis hypogaea*) Grown under Different Strength of Jute Agro Textile Mulch in India

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ABSTRACT

Aims: To evaluate the effects of jute agrotextile mulches on yield and yield attributes, dry matter accumulation, water use efficiency as well as accumulated agrometeorological indices and thermal utilization of groundnut.

Place and Duration of Study: The study was conducted in the experimental farm of Bidhan Chandra Krishi Viswavidyalaya, West Bengal, India during *kharif* season of 2017 and 2018.

Methodology: The experiment was carried in randomized block design with five treatments each of which was replicated four times Groundnut (variety J L-24) as a test crop. The treatments (T), composing different strength of jute agro textile (JAT) used as mulching material were as follows: T_1: 1000 GSM JAT, T_2: 800 GSM, T_3: 600 GSM, T_4: 400 GSM JAT and T_5: farmer's practice (control) where GSM is gram per square meter. All the data regarding the yield, yield attributes, water use efficiency and thermal utilization of the crop were recorded accordingly.

Results: Response of pod yield over control were 24.26 q/ha, 26.44 q/ha, 20.98 q/ha and 18.25q/ha in T_1, T_2, T_3, T_4, T_5 respectively. Though all the treatments showed increment over control, the highest result was found in T_2 and a further increase in strength of JAT showed a decrement in all aspects. The water use efficiency, at an average, increased by 69.12% due to the various treatments over control. Heat unit and thermal units use efficiencies were also highest in treatment T_2 which showed the most accurate utilization of thermal indices.

Conclusion: Therefore, among all the treatments T_2 exhibited the most promising effect on improving yield and other attributes along with maintaining sustainability as it might have provided the most favourable soil condition compared to other mulches for groundnut.

Key words: Groundnut, Jute agro textile, Mulching, Water use efficiency, Yield attributes, Thermal indices.

1. INTRODUCTION

Groundnut is a major oilseed crop of India and also an important agricultural export commodity. With annual all-season coverage of about 70 lakh hectares, globally India ranks first in groundnut acreage and with an output of approx. 80-85 lakh MT (in shell groundnuts), second in production. Although in various states of India groundnut is cultivated in one or more (kharif, rabi and summer) seasons, nearly 80% of acreage and production comes from kharif crop (June-October) [1]. It is an energy crop and needs a sufficient amount of nutrient to meet their requirement for growth, development and yield. Sustainable groundnut development can be achieved by diversifying the groundnut cropping system and moisture management practices. At this aspect mulching i.e. placing a layer of material (organic or inorganic) on the soil surface around the desired crop can be used for better crop production as well as moisture conservation [2]. However, other benefits of mulching are temperature regulation at the root zone and above ground growing environment, reduced nutrient leaching, altered insect and disease pressures, reduced soil compaction and soil erosion, increased soil porosity, improved soil organic matter or nutrient content and soil structure leading to enhanced crop production [3],[4],[5]. Mulching with synthetic (polyethylene film) or organic (crop residue) materials has been widely practiced for production of commercial widely spaced crops and vegetables including tomato, lettuce and others [6]. But to maintain sustainability, jute agro textile, made from 100% natural bust fibre has the potential to improve crop yield as well as soil fertility and productivity status as it contains natural substances for plant growth and releases essential plant nutrients through lignin decomposition without deteriorating the quality of environment [7]. It also provides an opportunity for recycling it assisting in waste management over synthetic mulch leading to environmental conservation. These agro-textile mulches reduce soil erosion from the impact of a heavy raindrop, surface runoff and wind, control weeds, conserve soil moisture, promote seedling establishment [8] and improve soil organic matter content [9]. Application of agro textile mulches increased the yield of broccoli (67.45%) and potato (61.03%) [10] compared to control where no mulching materials were used. Significant increase in average curd weight of broccoli has been reported by applying agro textile mulches [11]. Again, growth and development of crops during its entire growth period is greatly affected by several agro-climatic factors. The biomass production and duration of the crop growing period depends on the accumulation of solar radiation and different thermal or agro-meteorological indices viz., Growing degree days (GDD) or Heat unit (HU), Heliothermal units (HTU) and Photothermal units (PTU) [12].

Though researches have been done so far to increase groundnut productivity, use of jute agro textiles to improve yield of this crop as well as efficient thermal utilization and maintain the sustainability of environment has been lacking. So, a field experiment was undertaken to explore, in details, the effects of jute agro textile mulches on yield and yield attributes, growth rate, dry matter accumulation, water use efficiency as well as accumulated agrometeorological indices and thermal utilization of groundnut in the new alluvial zone of West Bengal, India.

2. MATERIALS AND METHODS

2.1. Study Area

The experiment was conducted for two consecutive years of 2017 and 2018 during *kharif* season from 2nd week of July to 3rd week of October at Regional Research Station, Bidhan Chandra Krishi Viswavidyalaya, New Alluvial zone, Nadia, West Bengal, India. The farm is located at $22^0$58' N L, $88^0$26' E L, with an altitude at 10.9 m above MSL having an average rainfall of 1500-1600 mm/year with variation of temperatures between 10^0- 38^0C. The soil of the experimental site is an typical alluvial soil (Typic ustifluvent), sandy loam in texture with almost neutral pH of 6.4, low in organic carbon (0.51%), available N (43.5 kg/ha), available P (9.05 kg/ha) and available k content (157.25 kg/ha).

2.2. Sampling Method and Data Analysis

The experiment was carried in randomized block design with five treatments each of which was replicated four times using Groundnut (variety J L-24) as a test crop. The treatments, composing different strength of jute agro textile (JAT) were as follows: T_1: 1000 GSM JAT, T_2: 800 GSM, T_3: 600 GSM, T_4: 400 GSM JAT and T_5: farmer's practice (control). The unit plot size was maintained by 20 square metre with spacing of 50cm between row to row and 10cm between plant to plant. Before sowing, seed treatment was done by Rhizobium culture (1 pack/bigha) and with Diathem M-45 (3 gm/kg) and also the soil surface was covered by the jute agro textiles maintaining proper gaps for sowing along with the basal dose of N-P-K @ 20-40-20 kg/ha. Sowing was done on each plot on second week of July for each year @ 100 kg/ha. The recommended package of practices was adopted for growing the crop. The crop was harvested on 3rd week of October.

All the data regarding the yield, yield attributes and water use efficiency of the crop were recorded. 100g pods of groundnut cultivar were taken from each replication randomly and shelled manually. Then kernels weights were taken to compute the shelling percentage [(kernel weight/ pod weight) x 100]. The moisture content of surface soil samples collected at 7 days interval of the entire growth period was determined by gravimetric method.

Agro-meteorological indices i.e. GDD, HTU and PTU were computed during whole growing periods for two years following the methods [13]. Computation of agrometeorological indices:

Growing degree day (GDD) = $(T_m - T_b)$

Heliothermal unit (HTU) = $[(T_m - T_b) \times BSH]$

Photothermal unit (PTU) = $[(T_m - T_b) \times DL]$

Where,

DL = Day length (Possible sunshine hours: from dawn to twilight)

BSH = Bright sunshine hours (Hour)

T_m= Daily mean temperature in ^oC.

T_b = Base temperature of groundnut 10^oC (GDD or heat units were computed considering 10°C being the base temperature for development of ground nut) [14],[15].

Thermal use efficiencies were evaluated in terms of both kernel yield and dry matter accumulation by using the formula [16].

Thermal use efficiencies = (Kernel yield or Dry matter accumulation / Accumulated thermal indices).

Necessary statistical analysis was worked out to interpret the effects of treatments as suggested [17]. The level of significance used in F and t test was p = 0.05. Critical difference values were calculated wherever the F test was significant.

3. RESULTS

3.1. Yield and Yield Attributes of Groundnut:

Results of the experiment revealed highly significant variation in growth and yield of groundnut under different treatments imposed (Table 1). Highest no. of kernel/pod (2.18), Shelling% and 100 kernel weight (78.16 & 95.76g respectively) were recorded in T_2 treatment i.e. in plot treated with 800 GSM jute agro textile. However, results with the lowest values were recorded in T_5 treatment (without jute agro textile). The response of pod yield over control due to each treatment were 24.26 q/ha (95.23%), 26.44 q/ha (103.85%), 20.98 q/ha (82.40%) and 18.25(71.68%) respectively in treatments T_1, $T_{2,}$ T_3 and T_4 respectively. Though all the strength of jute agro textile had increased yield over control, 800 GSM found to be most efficient among all. The variation in no. of kernel/pod, Shelling % and pod yield between years was non-significant. The result further reveals that yield and yield attributes were found to be positively and significantly correlated among themselves as indicated by the higher values of correlation coefficients, significant at 1% level of significance. Moreover, it was observed that water use efficiency and crop growth rate had a positive influence on yield and yield components (Table 5).

Table 1. Effect of different strength of JAT on yield and yield component of groundnut.

Treatment	No. of kernel/pod			Shelling%			100 Kernel Weight (g)			Kernel yield (q/ha)			Pod yield (q/ha)		
	Year1	Year2	Pooled	Year1	Year2	Pooled	Year1	Year2	Pooled	Year1	Year2	Pooled	Year1	Year2	Pooled
T_1 - 1000 GSM	2.16	2.16	**2.16**	75.41	72.90	**74.15**	92.35	95.18	**93.76**	36.94	36.79	**36.87**	48.96	50.50	**49.72**
T_2 - 800 GSM	2.18	2.18	**2.18**	80.48	75.84	**78.16**	94.78	96.75	**95.76**	40.80	40.31	**40.56**	50.65	53.16	**51.90**
T_3- 600 GSM	2.15	2.15	**2.15**	71.08	68.88	**69.98**	90.02	93.40	**91.71**	32.45	32.54	**32.49**	45.61	47.26	**46.44**
T_4 - 400 GSM	2.12	2.13	**2.13**	68.54	66.54	**67.54**	85.08	93.25	**89.16**	29.55	29.47	**29.51**	43.11	44.30	**43.71**
T_5 - Control	1.34	1.63	**1.48**	64.99	63.44	**64.22**	84.62	90.12	**87.38**	16.37	25.98	**21.17**	25.20	25.72	**25.46**
Grand Mean	1.99	2.05	**2.02**	72.10	69.52	**70.81**	89.37	93.74	**91.56**	31.22	33.02	**32.12**	42.70	44.19	**43.45**
SE (m)	0.081	0.124	0.074	2.002	0.955	1.109	1.093	0.551	0.612	1.310	0.600	0.721	0.728	0.645	0.486
CD (0.05)	0.248	0.384	0.216	6.169	2.941	3.237	3.369	1.697	1.786	4.036	1.850	2.103	2.224	1.987	1.419
Year*Treatment	SE (m)		0.105			1.656			0.866			1.019			0.688
	CD (0.05)		**NS**			**NS**			**2.526**			**2.974**			**NS**

3.2. Physiological Parameters of Groundnut:

The results of the physiological parameters of groundnut due to application of various strength of agrotextiles are presented in (Table 2). Although the variation of plant height, number of branch and leaves, occurred due to application of each of the strength in both the years, but better performance are observed with the application of 800 GSM except 50% flowering and 50% pegging stage. The physiological growth of the groundnut crops due to the application of various strength follows in the order of: 800 GSM > 1000 GSM > 600 GSM >400 GSM > control. The reverse result was found in 50% flowering (45.37 DAS) and 50% pegging (45.88 DAS) where the values become more in control plot than the plot received the treatments of agrotextiles. The 50% flowering and 50% pegging of groundnut significantly decreased ($P<0.05$) with the application of different types of jute agrotextiles over control.

Table 2. Effect of different strength of JAT on physiological parameter of groundnut.

Treatment		Plant height (cm)	50% Flowering (DAS)	50% Pegging (DAS)	No. of Branch	No. of leaves	No. of pod/plant
T_1 - 1000 GSM		26.35	41.12	43.75	19.14	145.83	38.96
T_2 - 800 GSM		27.41	40.12	42.50	21.56	148.50	40.98
T_3- 600 GSM		24.12	43.75	45.25	17.79	143.11	37.62
T_4 - 400 GSM		23.61	43.62	44.62	18.36	143.58	35.94
T_5 - Control		22.06	45.37	45.88	16.42	140.29	33.76
Grand Mean		24.71	42.80	44.40	18.65	144.26	37.45
SE (m)		0.391	0.224	0.204	0.277	0.656	0.366
CD (0.05)		1.140	0.653	0.595	0.809	1.913	1.067
Year*Treatment	**SE(m)**	0.552	0.316	0.289	0.927	0.392	0.517
	CD (0.05)	NS	NS	0.842	NS	NS	NS

3.3. Growth and Growth Rate of Groundnut:

The results of the dry matter production and crop growth rate influencing yield and growth of groundnut crop due to various strength of jute agrotextiles are presented in (Table 3).

Response of dry matter yield due to application of each agrotextiles increase over control 2244.4 kg/ha (32.90%), 2837.9 kg/ha (41.60%), 1688.4 kg/ha (24.75%) and 1163.4 kg/ha (17.05%) in treatments T_1, $T_{2,}$ T_3 and T_4 respectively. Crop growth rate was also increased over control by 26.05%, 42.30%, 24.93% and 17.09% in treatments T_1, $T_{2,}$ T_3 and T_4 respectively. The result further reveals that crop growth rate is positively and significantly correlated with number of pod/plant, number of kernel/pod, shelling percentage, 100 kernel weights, water use efficiency, kernel yield and pod yield at 1% level of significance (Table 5).

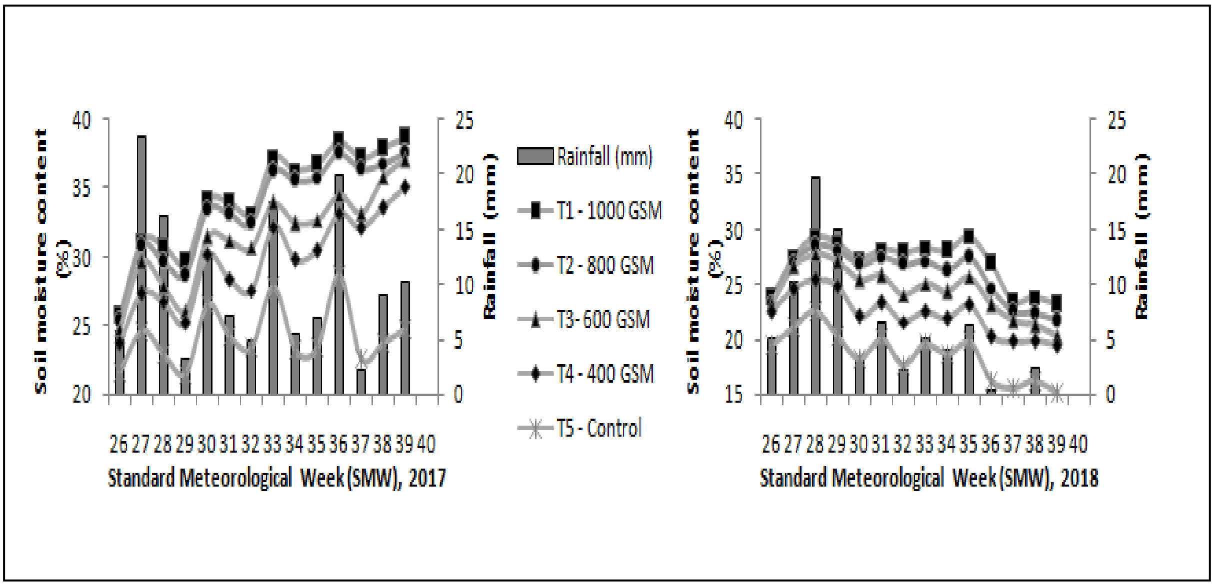
Table 3. Effect of different strength of JAT on growth and growth rate of groundnut.

Treatment	Dry matter production (kg/ha)			Crop growth rate (g/day/m2)		
	Year1	**Year2**	**Pooled**	**Year1**	**Year2**	**Pooled**
T_1 - 1000 GSM	9238.8	8894.4	**9066.6**	9.72	9.26	**9.50**
T_2 - 800 GSM	9557.0	9763.2	**9660.1**	10.06	10.17	**10.12**
T_3- 600 GSM	8953.8	8067.5	**8510.6**	9.42	8.42	**8.92**
T_4 - 400 GSM	8051.2	7920.0	**7985.6**	8.48	8.25	**8.36**
T_5 - Control	6804.4	6840.0	**6822.2**	7.16	7.12	**7.14**
Grand Mean	8521.0	8297.0	**8409.0**	8.97	8.65	**8.81**
SE (m)	5.313	15.244	8.072	0.057	0.154	0.082
CD (0.05)	**16.370**	**46.971**	**23.559**	**0.176**	**0.475**	**0.240**
Year*Treatment	SE (m)		11.415			0.116
	CD (0.05)		**33.318**			**0.339**

3.4. Soil moisture status and water use efficiency of groundnut:

Soil moisture content is an important factor which influences the activity of microorganisms in soil as well as the growth of the crop. So, the soil moisture content at 7 days interval for the entire growing period of groundnut under various treatments has been depicted in Fig.1 . Highest soil moisture percentage was found in that soil treated with 1000 GSM jute agrotextile and lowest in control.

Figure 1: Soil moisture status during the entire crop growth period under different treatments



The total moisture use and water use efficiency which is defined at the ratio between total yield and total water use during the growing period of crop are provided in Table 4 which shows that the moisture use efficiency, at an average, increased by 69.12% due to the various treatments over control. The result further reveals that water use efficiency is positively and significantly correlated with yield and its component at 1% level of significance (Table 5).

Table 4. Effect of different strength of JAT on total water use and water use efficiency of groundnut.

Treatment	Total water use (mm)			Water use efficiency (kg/ha-mm)		
	Year1	**Year2**	**Pooled**	**Year1**	**Year2**	**Pooled**
T_1 - 1000 GSM	523.60	525.72	**524.66**	9.34	9.60	**9.47**
T_2 - 800 GSM	534.60	535.08	**534.84**	9.47	9.93	**9.70**
T_3- 600 GSM	517.48	522.40	**519.94**	8.81	9.04	**8.93**
T_4 - 400 GSM	519.62	516.88	**518.25**	8.29	8.57	**8.43**
T_5 - Control	460.45	482.58	**471.51**	5.47	5.32	**5.40**
Grand Mean	511.15	516.53	**513.84**	8.28	8.49	**8.38**
SE (m)	0.224	0.828	0.429	0.141	0.129	0.096
CD (0.05)	**0.689**	**2.553**	**1.252**	**0.433**	**0.399**	**0.279**
Year*Treatment			0.607			0.135
			1.771			**NS**

Table 5. Correlation metrics involving yield and yield attributes characters of groundnut.

Correlations	No. of pod/plant	No. of kernel/pod	Shelling%	100 Kernel (w/g)	Kernel yield (Q/ha)	Water use efficiency (kg/ha-mm)	Crop growth rate (g/day/m2)	Pod yield (q/ha)
No. of pod/plant	1							
No. of kernel/pod	0.456**	1						
Shelling%	0.568**	0.362*	1					
100 Kernel(w/g)	0.663**	0.498**	0.315*	1				
Kernel yield(q/ha)	0.773**	0.632**	0.808**	0.627**	1			
Water use efficiency(kg/ha-mm)	0.746**	0.751**	0.669**	0.622**	0.882**	1		
Crop growth rate (g/day/m2)	0.727**	0.552**	0.738**	0.482**	0.820**	0.795**	1	
Pod yield(q/ha)	0.787**	0.730**	0.661**	0.606**	0.891**	0.983**	0.821**	1

**** Correlation is significant at the 0.01 level (2-tailed).**

3.5. Accumulated Agrometeorological Indices and Heat Units and Thermal Units Use Efficiencies:

Results revealed variations in the accumulation of thermal indices during two cropping season and their values are presented in table 6 . The higher accumulated Growing degree day (AGDD) and accumulated Photothermal units (APTU) over the entire crop growing season was required by the crop in first cropping season (1897.50 day °C and 23917.70 °C hour respectively) but accumulated Heliothermal units (AHTU) are higher in second cropping season (11484.10 °C hour) compared to first cropping season (8266.01 °C hour).

Table 6:Accumulation of agrometeorological indices by the crop in two cropping seasons

Agrometeorological indices	Year-1	Year-2
Accumulated Growing degree days (day °C)	1897.50	1818.70
Accumulated Heliothermal units (°C hour)	8266.01	11484.10
Accumulated Photothermal units (°C hour)	23917.70	22939.00

Heat unit and thermal units use efficiencies in terms of kernel yield and dry matter production have been presented in table 7 . Heat unit use efficiencies (HUE), heliothermal use efficiencies (HTUE) and photothermal use efficiencies (PTUE) were highest in treatment T_2 i.e. 800 GSM JAT among all treatments in terms of kernel yield in both cropping seasons but in the second season the HUE and PTUE are higher (HUE: 2.216 kg ha-1 day°C^{-1} , PTUE: 0.176 kg ha-1 °Chour^{-1}) and HTUE is lower (0.351 kg ha-1 °Chour^{-1}) compared to the first season. In terms of dry matter production, again the HUE, HTUE, PTUE are highest in treatment T_2 in both growing seasons but in second season the HUE and PTUE are higher (HUE: 5.368 kg ha-1 day°C^{-1} , PTUE: 0.426 kg ha-1 °Chour^{-1}) and HTUE is lower (0.850 kg ha-1 °Chour^{-1}) compared to the first season. T_5 showed lowest heat units and thermal units use efficiencies both in terms of kernel yield and dry matter production.

Table 7: Effects of different strength of JAT on heat units and thermal units use efficiencies of ground nut

Treatments (Strength of JAT)	Heat unit use efficiencies (kg ha-1 day°C^{-1})		Heliothermal use efficiencies (kg ha-1 °Chour^{-1})		Photothermal use efficiencies (kg ha-1 °Chour^{-1})	
	Year-1	Year-2	Year-1	Year-2	Year-1	Year-2
In terms of kernel yield (kg/ ha)						
T1 - 1000 GSM	1.947	2.023	0.447	0.320	0.154	0.160
T2 - 800 GSM	2.150	2.216	0.494	0.351	0.171	0.176
T3- 600 GSM	1.710	1.789	0.393	0.283	0.136	0.142
T4 - 400 GSM	1.557	1.620	0.357	0.257	0.124	0.128
T5 - Control	0.863	1.428	0.198	0.226	0.068	0.113
In terms of dry matter (kg/ ha)						
T1 - 1000 GSM	4.869	4.891	1.118	0.774	0.386	0.388
T2 - 800 GSM	5.037	5.368	1.156	0.850	0.400	0.426
T3- 600 GSM	4.719	4.436	1.083	0.702	0.374	0.352
T4 - 400 GSM	4.243	4.355	0.974	0.690	0.337	0.345
T5 - Control	3.586	3.761	0.823	0.596	0.284	0.298

4. DISCUSSIONS

The superiority of biodegradable JAT mulch over control to increase yield in groundnut might be due to the beneficial effect of increased moisture conservation, increased organic carbon and nutrient status along with high weed control efficiency. It was evidenced that the highest yield of high value crops like capsicum (8.2 t ha^{-1}) and pointed gourd (1.4 t ha^{-1}) in geo-textile mulched plot compared to control which was due to higher heat and moisture conservation resulted in better root growth and increased microbial activity in the rhizosphere. As a result availability of nutrients through mineralization and subsequent uptake by crops might had increased [18]. Again in another study, the yield of tomato had increased 51.8 % over control for the use of jute agro textile as mulching material [19]. In the case of soil moisture content, treated plot showed higher value compared to control because of their increased water retention capacity due to increased infiltration and reduced evaporation for the mulch. Again the increased moisture content was also due to higher amount of organic matter as JAT decomposed over time. High surface soil moisture due to an increase in organic matter content in soil has been reported in many studies [20]. Again, the addition of organic matter to soil causes higher yield over less amount of water leading to an increase in water use efficiency which has been reported in many cases [21], [22]. In case of thermal use efficiencies, the differences in results were occurred due to the application of different strength of JAT [10].

5. CONCLUSION

Based on the findings of the experiment, it is observed that the use of jute agrotextile as mulching component is beneficial for getting higher productivity of groundnut over the control. Though all the treatments showed better results over control, the best result was found in treatment T_2 i.e. 800 GSM JAT. Further increment in the strength of JAT did not show a better result but decrement in all aspects. So, the treatment T_2 i.e. 800 GSM thickness might have provided the most favourable soil condition compared to other mulches to groundnut and resulted the highest growth and yield of the crop. Again among the various strength of JAT, treatment T_2 showed the highest heat unit and thermal units use efficiencies. Therefore, it is apparent form the present study that jute agrotextiles can serve as better mulch for groundnut crop and thus improve the yield and yield attributes of groundnut by maintaining adequate soil moisture, an optimum thermal condition leading to favourable nutrient supply to crops and by proper utilization of thermal indices.

6. COMPETING INTERESTS

Authors have declared that no competing interests exist.

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8. Authors' contributions

This work was carried out in collaboration among all authors. Author AS collected the data, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author AG designed the study. Authors AG, PKT and SKD assisted in the analyses of the study and refined the manuscript. All authors read and approved the final manuscript.