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Agrometeorological Indices, Crop Phenology and Yield of Pigeon pea as Influenced by Pigeon pea (*Cajanus cajan* L.) based Intercropping System

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A B S T R A C T

A field investigation was conducted at experimental farm, Department of Agricultural Meteorology, located at college of Agriculture, V.N.M.K.V, Parbhani during *kharif* season of 2019-20. The experiment was laid out in RBD with three replication, under this study there were nine treatments viz. T_1 (Pigeon pea + Sorghum), T_2 (Pigeon pea + Maize), T_3 (Pigeon pea + Soybean), T_4 (Pigeon pea + Sesamum), T_5 (Pigeon pea), T_6 (Sorghum), T_7 (Maize), T_8 (Soybean), T_9 (Sesamum). In pigeon pea the highest total agrometeorological indices (GDD, HTU and PTU) accumulated by intercropped treatment T_1 as compared to sole, by sorghum, maize and sesamum was highest in intercropped treatment i.e. (T_1), (T_2) and (T_4) than in sole whereas, the accumulated agrometeorological indices by soybean was highest in sole treatment i.e. (T_8) than intercropped (T_3). Significantly higher Pigeon pea equivalent yield was attained with treatment T_3 followed by T_4, lowest recorded in T_1 intercropping system. The highest stalk / stover yield was attained by T_2 as compared to sole whereas, lowest was recorded in T_8. Treatment T_3 performed better than other and this treatment was better in terms of growth and yield attributing characters.

Introduction

Pigoen pea is (*Cajanus cajan* L.) an important pulse crop, produced and consumed in India, grown during *kharif* season. It is a long duration crop with initial slow growth rate, so there is ample scope of growing short duration inter crops which help in getting additional yield and income. Intercropping is defined as growing two or more crops simultaneously on the same piece of land with a definite row pattern. The difficulty and risk of growing sole crops can also be minimized through intercropping. The yield is enhanced if intercropping components have different efficacies in consumption of environmental

resources, they will make better use of the resources (Willey, 1979). Intercropping increased the amount of absorption PAR, light interception and shading in intercropping compared to sole (Ghanbari *et al.*, 2010). Intercropping helps in variation of microclimate, especially for light intensity, relative humidity and temperature (He *et al.*, 2012).

Light is an important competition factor since it can't be stored and is lost if not absorbed (Awal *et al.*, 2006). Rao, (1982) reported that decrement in pods per plant in intercropping might be due to competition for light, nutrients, and moisture which reduced the growth of component crop. The adoption of cropping system that either increases the interception of radiation or maintains higher radiation use efficiency productivity per unit incident radiation might be improved. The intercrops produced substantially smaller fresh weights in either planting patter compared to the yields of sole crop. However, intercropping system as a whole resulted in higher economic returns as compared to the sole crop.

Materials and Methods

A field experiment was conducted during the *kharif* season of 2019-20 also the weather data for the relevant period of experiment recorded at experimental farm of the Department of Agricultural Meteorology located at College of Agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. The field selected for experiment is uniform with typical black cotton soil. The daily observations converted on weekly basis and used for analysis.

In the present investigation Randomized Block Design (RBD) used with single sowing date (2 July 2019) at the nine treatments with three replication of different crops with varieties were tried. The size of each plot was 4.5 m × 5.4 m. The crops used in the experiment were Pigeon pea (BDN-711), Sorghum (Parbhani Shakti), Maize (Dekalb), Sesamum (MAUS-158) and Soybean (JLT-408). T_1 (Pigeon pea + Sorghum), T_2 (Pigeon pea + Maize), T_3 (Pigeon pea + Soybean), T_4 (Pigeon pea + Sesamum), T_5 (Pigeon pea), T_6 (Sorghum), T_7 (Maize), T_8 (Soybean) and T_9 (Sesamum) treatments were used with 4:2 ratio of component crop.

On the basis of Govt. minimum support price (MSP) of pigeon pea, sorghum, maize, soybean and maize seed the yield of each treatment for both component crops converted into crop equivalent yield of pigeon pea crop. The pigeon pea equivalent (PYE) (Kg ha^{-1}) is calculated as follows:

$$PEY = P_{ab} + \frac{N_{ab} \times N_{mp}}{P_{mp}}$$

Where,

PEY = Pigeon pea equivalent yield (Kg ha^{-1}), P_{ab} = Yield of pigeon pea in intercropping system (Kg ha^{-1}), N_{ab} = Yield of intercrop (sorghum, maize, soybean and sesamum) in intercropping system (Kg ha^{-1}), N_{mp} = Market price of intercrop (sorghum, maize, soybean and Sesamum) (Rs Kg^{-1}), P_{mp} = Pigeon pea market price (Rs Kg^{-1})

Computation of Agrometeorological indices (GDD, HTU and PTU)

Growing Degree Days (GDD)

(°C day)

Growing Degree Days is defined as "the sum over the growing season of a crop of the difference between the daily temperature and a reference temperature". The total GDD for

different phenophases were determined by the following formula. (Nuttonson, 1955). The base temperature (8°C) for all the crops in the study, following Schenkler and Roberts, (2009). This is because the literature indicates that the base temperature for most crops ranges between 5 to 10°C (Luo, 2011).

$$GDD=\sum[(Tmax+Tmin)/2]-Tb$$

Where,

Tmax = Daily maximum air temperature (°C),
Tmin = Daily minimum air temperature (°C),
Tb = Base temperature (°C)

Helio Thermal Units (HTU)

(°C day hrs)

The HTU may be defined as "the accumulated product of GDD and bright sunshine hours between the developmental thresholds for each day." The sum of HTU for each phenophase was worked out by following equation (Singh *et al.,* 1990).

$$HTU = GDD \times Mean\ BSS$$

Where,

BSS = Bright Sunshine Hours

Photo Thermal Units (PTU)

(°C day hrs)

PTU may be defined as "the product of growing degree days and the day length." PTU was computed by using following formula. (Gudadhe *et al.,* 2013). Day length for sorghum, soybean, sesamum and pigeon pea (10 hrs) and for maize (12 hrs). (Qiang *et al.,* 2015).

$$PTU = GDD \times Day\ length$$

Results and Discussion

The effect of weather parameters on crop physiology was expressed directly on the phenology. The duration required for each phenophase as influenced by different treatments. In the present investigation, the whole life cycle of crops (from sowing to physiological maturity) was divided into various distinct phenophases on the basis of external morphological characteristics. Thermal time is widely used for describing the temperature responses to growth and development of crops. GDD, HTU and PTU required for completion of different phenophases of pigeon pea were worked out.

Agrometeorological Indices

Accumulated GDD, HTU and PTU in Pigeon pea

The data in table 1 revealed the highest total agrometeorological indices was accumulated by treatment (T_1) i.e. pigeon pea intercropped with sorghum as compared to treatment (T_5) i.e. sole pigeon pea. The result indicated that the total GDD, HTU and PTU accumulated from sowing to physiological maturity ranged between 3988.3 to 4315.7°C day, 22907.1 to 25021.4°C day hrs and 39883.0 to 43156.5°C day hrs among the treatments T_1, T_2, T_3, T_4 and T_5 respectively.

Accumulated GDD, HTU and PTU in Sorghum

The data in table 2 revealed that the highest total agrometeorological indices was accumulated by treatment (T_1) i.e. pigeon pea intercropped with sorghum as compared to treatment (T_6) i.e. sole sorghum. The result indicated that the total GDD, HTU and PTU accumulated from sowing to physiological maturity ranged between 3006.5 to 3109.8°C day, 15299.8 to 16143.9°C day hrs and

30065.0 to 31097.5°C day hrs among the treatment T_1 and T_6 respectively.

Accumulated GDD, HTU and PTU in Maize

The data in table 3 revealed that the the highest total agrometeorological indices was accumulated by treatment (T_2) i.e. pigeon pea intercropped with maize as compared to treatment (T_7) i.e. sole maize. The result indicated that the total GDD, HTU and PTU accumulated from sowing to physiological maturity ranged between 2641.3 to 2743.6°C day, 13284.8 to 14029.6°C day hrs and 31695.6 to 32923.2°C day hrs among the treatment T_2 and T_7 respectively.

Table.1 Accumulated GDD, HTU and PTU in Pigeon pea

Growing Degree Days						
Treatment	**Phenophases**					
	P_1	**P_2**	**P_3**	**P_4**	**P_5**	**Total**
T_1: (Pigeonpea + Sorghum)	247.3	1228.5	2816.4	3055.4	4315.7	4315.7
T_2: (Pigeonpea + Maize)	247.3	1228.5	2791.8	3030.8	4274.6	4274.6
T_3: (Pigeonpea + Soybean)	247.3	1201.9	2742.0	2957.0	4184.7	4184.7
T_4: (Pigeonpea + Sesamum)	247.3	1174.9	2690.7	2882.7	4071.9	4071.9
T_5: (Sole Pigeon pea)	247.3	1148.5	2639.1	2808.1	3988.3	3988.3
Gmean	247.3	1196.5	2736.0	2946.8	4167.0	-
Helio Thermal Units						
Treatment	**Phenophases**					
	P_1	**P_2**	**P_3**	**P_4**	**P_5**	**Total**
T_1: (Pigeonpea + Sorghum)	840.8	5158.1	14367.6	15443.1	25021.4	25021.4
T_2: (Pigeonpea + Maize)	840.8	5158.1	14225.5	15372.7	24825.2	24825.2
T_3: (Pigeonpea + Soybean)	840.8	4945.7	13724.0	14949.5	24156.9	24156.9
T_4: (Pigeonpea + Sesamum)	840.8	4922.2	13562.0	14810.0	23491.2	23491.2
T_5: (Sole Pigeon pea)	840.8	4896.2	13243.6	14409.7	22907.1	22907.1
Gmean	840.8	5016.1	13824.5	14997.0	24080.4	-
Photo Thermal Units						
Treatment	**Phenophases**					
	P_1	**P_2**	**P_3**	**P_4**	**P_5**	**Total**
T_1: (Pigeonpea + Sorghum)	2473.0	12285.0	28163.5	30553.5	43156.5	43156.5
T_2: (Pigeonpea + Maize)	2473.0	12285.0	27918.4	30308.4	42745.9	42745.9
T_3: (Pigeonpea + Soybean)	2473.0	12019.0	27419.5	29569.5	41846.0	41846.0
T_4: (Pigeonpea + Sesamum)	2473.0	11749.0	26906.5	28826.5	40718.5	40718.5
T_5: (Sole Pigeon pea)	2473.0	11485.0	26391.0	28081.0	39883.0	39883.0
Gmean	2473.0	11964.6	27359.8	29467.8	41670.0	-

P_1 – Sowing to emergence P_2 – Emergence to branching
P_3 – Branching to flowering P_4 – Flowering to pod formation
P_5 – Pod formation to physiological maturity

Table.2 Accumulated GDD, HTU and PTU in Sorghum

Growing Degree Days								
Treatment	**Phenophases**							
	P_1	**P_2**	**P_3**	**P_4**	**P_5**	**P_6**	**P_7**	**Total**
T1:(Pigoenpea+Sorghum)	160.5	1395.2	1703.7	1978.3	2208.4	2462.0	3109.8	3109.8
T6:(Sole Sorghum)	160.5	1392.0	1676.9	1950.5	2150.7	2381.2	3006.5	3006.5
G mean	160.5	1393.6	1690.3	1964.4	2179.6	2421.6	3058.2	-
Helio Thermal Units								
Treatment	**Phenophases**							
	P_1	**P_2**	**P_3**	**P_4**	**P_5**	**P_6**	**P_7**	**Total**
T1:(Pigoenpea+Sorghum)	497.6	6547.4	8213.3	9064.6	10510.1	12386.7	16143.9	16143.9
T6:(Sole Sorghum)	497.6	6285.7	8052.1	8818.2	9832.4	11422.9	15299.8	15299.8
G mean	497.6	6416.6	8132.7	8941.4	10171.3	11904.8	15721.9	-
Photo Thermal Units								
Treatment	**Phenophases**							
	P_1	**P_2**	**P_3**	**P_4**	**P_5**	**P_6**	**P_7**	**Total**
T1:(Pigoenpea+Sorghum)	1605.0	13951.5	17036.5	19782.5	22083.5	24619.5	31097.5	31097.5
T6:(Sole Sorghum)	1605.0	13920.0	16769.0	19505.0	21507.0	23812.0	30065.0	30065.0
G mean	1605.0	13935.8	16902.8	19643.8	21795.3	24125.8	30581.3	-

P_1 – Sowing to emergence P_2 Emergence to penical initiation P_3 – Penical initiation to flag leaf stage
P_4 – Flag leaf stage to boot stage P_5 – Boot stage to flowering P_6 – Flowering to dough stage
P_7 – Dough stage to physical maturity

Table.3 Accumulate GDD, HTU and PTU in Maize

Growing Degree Days							
Treatment	**Phenophases**						
	P_1	**P_2**	**P_3**	**P_4**	**P_5**	**P_6**	**Total**
T_2:(Pigeonpea+Maize)	385.7	1314.5	1522.8	1644.7	2365.0	2743.6	2743.6
T_7:(Sole Maize)	385.7	1283.0	1465.2	1567.0	2285.2	2641.3	2641.3
G mean	385.7	1298.8	1494.0	1605.9	2325.1	2692.5	-
Helio Thermal Units							
Treatment	**Phenophases**						
	P_1	**P_2**	**P_3**	**P_4**	**P_5**	**P_6**	**Total**
T_2:(Pigeonpea+Maize)	1812.8	6085.3	7418.4	8027.9	11341.3	14029.6	14029.6
T_7:(Sole Maize)	1812.8	5671.2	6946.6	7669.8	10614.0	13284.8	13284.8
G mean	1812.8	5878.3	7182.5	7848.9	10977.7	13657.2	-
Photo Thermal Units							
Treatment	**Phenophases**						
	P_1	**P_2**	**P_3**	**P_4**	**P_5**	**P_6**	**Total**
T_2:(Pigeonpea+Maize)	4628.4	15774.0	18273.6	19736.4	28380.0	32923.2	32923.2
T_7:(Sole Maize)	4628.4	15396.0	17582.4	18804.0	27422.4	31695.6	31695.6
G mean	4628.4	15585.0	17928.0	19270.2	27901.2	32309.4	-

P_1 – Sowing to seedling P_2 – Seedling to grandgrowth
P_3 – Grandgrowth to tasseling P_4 – Tasseling to silking
P_5 – Silking to milk stage P_6 – Milk stage to physical maturity

Table.4 Agrometeorological Indices (GDD, HTU and PTU) in Soybean

Growing Degree Days							
Treatment	**Phenophases**						
	P_1	**P_2**	**P_3**	**P_4**	**P_5**	**P_6**	**Total**
T_3:(Pigeonpea+Soybean)	644.1	1446.7	1628.2	1773.2	1942.6	2537.3	2537.3
T_8:(Sole Soybean)	644.1	1503.6	1705.6	1878.6	2100.7	2721.3	2721.3
G mean	644.1	1475.2	1666.9	1825.9	2021.7	2629.3	-
Helio Thermal Units							
Treatment	**Phenophases**						
	P_1	**P_2**	**P_3**	**P_4**	**P_5**	**P_6**	**Total**
T_3:(Pigeonpea+Soybean)	3864.6	6914.5	8239.5	8543.9	9018.2	12764.8	12764.8
T_8:(Sole Soybean)	3864.6	7302.6	8393.4	8739.4	9694.4	13914.5	13914.5
G mean	3864.6	7108.6	8316.5	8641.7	9356.3	13339.7	-
Photo Thermal Units							
Treatment	**Phenophases**						
	P_1	**P_2**	**P_3**	**P_4**	**P_5**	**P_6**	**Total**
T_3:(Pigeonpea+Soybean)	6441.0	14467.0	16282.0	17732.1	19425.9	25373.2	25373.2
T_8:(Sole Soybean)	6441.0	15035.9	17055.8	18785.7	21007.0	27213.0	27213.0
G mean	6441.0	14751.5	16668.9	18258.9	20216.5	26293.1	-

P_1 – Sowing to seedling P_2 – Seedling to branching
P_3 – Branching to flowering P_4 – Flowering to pod formation
P_5 – Pod formation to grain formation P_6 – Grain formation to physical maturity

Table.5 Accumulated GDD, HTU and PTU in Sesamum

Growing Degree Days						
Treatment	**Phenophases**					
	P_1	**P_2**	**P_3**	**P_4**	**P_5**	**Total**
T_4:(Pigeonpea+Sesamum)	134.3	664.7	883.0	1163.3	2447.3	2447.3
T_9:Sole Sesamum)	134.3	636.2	830.7	1082.0	2339.1	2339.1
G mean	134.3	650.5	856.9	1122.7	2393.2	-
Helio Thermal Units						
Treatment	**Phenophases**					
	P_1	**P_2**	**P_3**	**P_4**	**P_5**	**Total**
T_4:(Pigeonpea+Sesamum)	456.6	4063.3	4390.8	5203.7	12131.6	12131.6
T_9:Sole Sesamum)	456.6	3819.3	4150.0	4903.9	11189.2	11189.2
G mean	456.6	3941.3	4270.4	5053.8	11660.4	-
Photo Thermal Units						
Treatment	**Phenophases**					
	P_1	**P_2**	**P_3**	**P_4**	**P_5**	**Total**
T_4:(Pigeonpea+Sesamum)	1343.1	6647.2	8830.0	11633.2	24472.7	24472.7
T_9:Sole Sesamum)	1343.1	6361.6	8306.9	10820.1	23391.0	23391.0
G mean	1343.1	6504.4	8568.5	11226.7	23931.9	-

P_1 – Sowing to emergence P_2 – Emergence to branching
P_3 – Branching to flowering P_4 – Flowering to capsules
P_5 – Capsules to physical maturity

Table.6 Seed yield of crops

Treatments	Seed yield(Kg ha^{-1})		
	Main	Inter	Pig. Equi. Yield
T_1 (Pigeonpea + Sorghum)	597	602	861
T_2 (Pigeonpea + Maize)	837	1453	1277
T_3 (Pigeonpea + Soybean)	1283	345	1503
T_4 (Pigeonpea + Sesamum)	1292	99	1402
T_5 (Sole Pigeon pea)	1349	-	1249
T_6 (Sole Sorghum)	3280	-	3280
T_7 (Sole Maize)	4108	-	4108
T_8 (Sole Soybean)	1410	-	1410
T_9 (Sole Sesamum)	285	-	285
S.E±	-	-	54.62
CD at 5%	-	-	165.16
G Mean	1604.6	624.8	1260.8

Table.7 Stalk/Stover yield of crops

Treatments	Stalk/Stover yield(Kg ha^{-1})		
	Main	Inter	Pig. Equi. Yield
T_1 (Pigeonpea + Sorghum)	1970	589	2559
T_2 (Pigeonpea + Maize)	1960	1128	3088
T_3 (Pigeonpea + Soybean)	2080	640	2720
T_4 (Pigeonpea + Sesamum)	2096	162	2258
T_5 (Sole Pigeon pea)	2120	-	2120
T_6 (Sole Sorghum)	2284	-	2284
T_7 (Sole Maize)	2884	-	2884
T_8 (Sole Soybean)	1418	-	1418
T_9 (Sole Sesamum)	1734	-	1734
G Mean	2060.7	629.8	2340.6

Accumulated GDD, HTU and PTU in Soybean

The data in table 4 revealed the highest total agrometeorological indices was accumulated by treatment (T_8) i.e. sole soybean as compared to treatment (T_3) i.e. pigeon pea intercropped with soybean. The result indicated that the total GDD, HTU and PTU accumulated from sowing to physiological maturity ranged between 2537.3 to 2721.3°C day, 12764.8 to 13914.5°C day hrs and 25373.2 to 27213.0°C day hrs among the treatment (T_3 to T_8).

Accumulated GDD, HTU and PTU in Sesamum

The data in table 5 revealed that the highest total agrometeorological indices was accumulated by treatment (T_4) i.e. pigeon pea intercropped with sesamum as compared to treatment (T_9) i.e. sole sesamum. The result indicated that the total GDD, HTU and PTU

accumulated from sowing to physiological maturity ranged between 2339.1 to 2447.3°C day, 11189.2 to 12131.6°C day hrs and 23391.0 to 24472.7°C day hrs among the treatment (T_4 to T_9).

Yield Parameter

Seed/Grain yield (Kg ha^{-1})

The data from Table 6 shows that mean pigeon pea equivalent yield (PEY) (Kg ha^{-1}) was significantly influenced by different treatment. The pigeon pea yield was significantly affected by the intercropping pattern. There was a significant difference between PEY with various pigeon pea based intercropping systems. The PEY was obtained highest from the pigeon pea + soybean (T_3) intercropping system (1503 Kg ha^{-1}), followed by the pigeon pea + sesamum (T_4) intercropping system (1402 Kg ha^{-1}), pigeon pea + maize (T_2) intercropping system (1277) than the sole pigeon pea (T_5) (1249 Kg ha^{-1}). Whereas, the PEY was obtained lowest from pigeon pea + sorghum (T_1) intercropping system (861 Kg ha^{-1}) as compared to sole pigeon pea. However, in the PEY it was observed that the treatment T_3 was significantly superior than other treatment, which was at par with the treatment T_4.

The legume and legume as main crop and intercrop might have symbiotic effect with each other and reduced the competition for moisture and nutrients between the component crops and significantly increased yield of both component crops. Hence, the PEY from pigeon pea + soybean intercropping treatment was highest. Similar result was reported by Waghmare *et al.,* (1982) and Kathmale *et al.,* (2014). Sole pigeon pea seemed to have been more remunerative than pigeon pea + sorghum intercropping probably because of intense inter - specific competition from the sorghum component and subsequently reduced profits.

On the other hand, maize crop adversely affected the yield of pigeon pea however the PEY was more than sole pigeon pea because of good yield of maize but it could not compensate the losses occurred due to reduced pigeon pea yield. Similar result was observed by Egbe and Idoko, (2012) and Tiwari *et al.*, (2012). So it was observed that sole pigeon pea gave significantly higher grain yield than the intercropped. However, intercropping systems gave higher PEY over sole pigeon pea except from pigeonpea + sorghum intercropping treatment. Similar results were observed by Ito *et al.,* (1993), Singh and Singh, (1994), Rekha and Dhurua, (2009), and Reddy *et al.,* (2015).

Stalk/Stover yield (Kg ha^{-1})

The data from Table 7 shows that mean pigeonpea stalk/stover yield (Kg ha^{-1}) was significantly influenced by different treatments. The stalk/stover yield was significantly affected by the intercropping patter. It was significantly superior in treatment T_2 (3088 Kg ha^{-1}) i.e. pigoenpea + maize as compared to all treatment and lowest in treatment T_8 (1418 Kg ha^{-1}) i.e. sole soybean. Among pigeon pea based intercropping systems, higher stover yield of sorghum as an intercrop was recorded in pigeon pea + sorghum system. Hence, the pigeon pea stalk/stover yield under Pigeon Pea + sorghum was highest as compared to pigeon pea yields with other intercrops. Similar result was reported by Kathmale *et al.,* (2014).

The highest agrometeorological indices was accumulated by treatment (T_1) i.e. pigeon pea intercropped with sorghum as compared to sole pigeon pea i.e. T_5, by sorghum, maize and sesamum were highest in intercropped treatment i.e. (T_1), (T_2) and (T_4) than in sole whereas, accumulated by soybean was highest in sole treatment i.e. (T_8) than intercropped (T_3). Variations in agrometeorological indices

for various phonological stages indicated that accumulated temperature can be utilized for dry biomass and crop yield forecast. Significantly higher PEY was attained with treatment T_3 (Pigeon pea + Soybean) followed by T_4 (Pigeon pea + Sesamum). This might be due to no competition between main crop and intercrop for growth, development and for above ground and below ground resources as crop was of shorter duration. The lowest PEY was recorded in (T_1) pigeon pea + sorghum intercropping system and might be due to intense inter-specific competition. In the pigeon pea based intercropping system, highest stalk/stover yield were attained by T_2 i.e. pigeon pea intercropped with maize as compared to sole whereas, lowest stalk/stover yield was recorded in T_8 i.e. sole soybean. Treatment T_3 performed better than other and this treatment was better in terms of growth and yield attributing characters.

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