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RESEARCH PAPER

Changes in growth and yield of pigeonpea genotypes under different growing environments

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Abstract: A field experiment was conducted at Regional Agricultural Research Station (RARS), Vijayapura, during *kharif* 2021. The experiment was laid out in a split-plot design assigning four sowing windows to main plots *viz*., 1st fortnight of June, 2nd fortnight of June, 1st fortnight of July and 2nd fortnight of July, whereas genotypes to subplot *viz.,* TS-3R, GRG-152 and GRG-811 with three replications. The results revealed that the seed yield progressively decreased with a delay in sowing. A significantly higher seed yield was recorded under early sowings in the 1st and 2nd fortnight of June (1539 and 1535 kg ha^{-1}, respectively) and were statistically similar for seed yield. Among the genotypes studied, TS-3R recorded a significantly higher seed yield (1455 kg ha^{-1}) than other genotypes, which was on par with GRG-152 (1424 kg ha^{-1}). The increase in the yield was attributed to better growth and yield attributes coupled with more rainfall (521 mm) received during the cropping period. The pigeonpea sown in 1st fortnight of June recorded higher plant height (196.3 cm), primary branch per plant (14.00), secondary branch per plant (18.21), the total number of pods (117.7), seed weight per plant (53.1) and 100-seed weight (12.5) compared to delayed sowings. The interaction of pigeonpea genotype TS-3R sown in 2nd fortnight of June recorded a significantly higher seed yield (1550 kg ha^{-1}), which was closely followed by and statistically on par with the interaction of GRG-152 sown in 1st fortnight of June (1542 kg ha^{-1}). The study concludes that the early sowing of pigeonpea genotypes TS-3R and GRG-152 is better for realizing maximum productivity and profitability in the northern dry zone of Karnataka.

Key words: Biological yield, Pod damage, Sowing window, Standard meteorological week

Introduction

Pigeonpea (*Cajanus cajan* L.) is an important grain legume that belongs to the Fabaceae (Leguminaceae) family and is a widely cultivated pulse crop in India. It is a drought tolerant, deep-rooted, often cross-pollinated, C_3, short-day plant and hypogeal germination in nature. It is a common food grain crop and offers nutritional security due to its richness in protein (21%) with essential amino acids such as methionine, lysine and tryptophan, along with mineral supplementation, *viz*., iron and iodine. In addition, it also has the unique property of maintaining and restoring soil fertility through biological nitrogen fixation and improvement of the physical properties of the soil by its deep root system. The growth and development of pigeonpea vary from location to location due to variability in agro-climatic and soil-water-related parameters. Even in the same area, variability in growth takes place due to different growing environments created by sowing dates, cultivars and other cultural and management practices (Ahlawat and Rana, 2005).

Pigeonpea is grown throughout the tropical and sub-tropical regions of the world and warmer temperature regions between 30^{0}N and 35^0 S latitudes. India's significant area under pigeonpea lies between 14^0 and 28^0 N latitudes. India has the distinction of being the world's largest producer and consumer of pulses, including pigeonpea. The area under pigeonpea cultivation in India is 4.72 m ha and production of 4.31 m tonnes with a productivity of 914 kg ha^{-1} (Indiastat, 2021). Maharashtra ranks first in terms of area (27.73%), followed by Karnataka (19.97%) and Madhya Pradesh (14.60%). Karnataka is one of the pigeonpea growing states, having an area of 1.63 m ha with a production of 1.23 m tonnes and productivity of 759 kg ha^{-1} (Indiastat, 2021).

Time of sowing is one of the most essential agronomic factors for realizing the potential yield of improved varieties as it helps achieve complete harmony between the vegetative and reproductive growth stages (Singh *et al*., 2012). Sowing time also plays a vital role in dry matter accumulation by the crop. Early sown crops may accumulate more dry matter, whereas late sown crops may reduce biomass accumulation and yield. Many researchers found that delayed sowings beyond the optimum period resulted in low grain yields in pigeonpea (Behera *et al*., 2018) and chickpea (Niveditha *et al*., 2022). Further, genotypes may vary in productivity and are equally important in realizing the potential yield of this crop. Long-duration genotypes produce a higher yield than early-maturing genotypes, but they take more time to mature, which may delay the sowing of succeeding crops (Singh, 2006). Various factors responsible for the low yield of pigeonpea at the farmers' fields are the unawareness of farmers about the optimum date of sowing, selection of suitable genotype, improper plant population, insufficient plant protection measures and imbalanced use of fertilizers. Among these factors, proper sowing time and selection of suitable genotypes are of greater importance in the current climate change scenario. The variation in weather scenarios through sowing times affects the phenology and reduces the yielding potential of a variety. Hence, it is necessary to identify the best sowing time with a genotype suited to changes in the environment for the sustained production of pigeonpea. Still, farmers have a great problem tackling such situations in pigeonpea by adapting various agronomic measures such as modifying sowing windows and selecting suitable varieties so that they can get better yields and economic returns. This research will pave the way to effectively sort out the pigeonpea cultivation problem under changing climate scenarios. It is, therefore, essential to study how pigeonpea genotypes perform in changing weather scenarios through sowing windows, especially in the Northern Dry Zone of Karnataka. Keeping this in view, the experiment was executed at Regional Agricultural Research Station, Vijayapura.

Material and methods

The experiment was conducted at the Regional Agricultural Research Station (RARS), Vijayapura. It is located at a latitude of 16^0 46' 15.16'' North, a longitude of 75^0 44' 53.78'' East and an altitude of 593.8 meters above the mean sea level. The experimental site is in the jurisdiction of the Northern Dry Zone of Karnataka (Zone 3). The soil of the experimental site is medium-deep black and the texture of the soil is a clayey loam belonging to the order *Vertisols*. The pH of the soil is 8.47, organic carbon (0.51%), available N (168.0 kg ha^{-1}), available P_2O_5 (31.0 kg ha^{-1}) and available K_2O (357.8 kg ha^{-1}). The RARS, Vijayapura has a semi-arid climatic situation. The weather data was recorded from the meteorological observatory, RARS, Vijayapura during the experimental year (*Kharif* 2021) and the mean of the last 40 years (1981-2020). There was little deviation in monthly maximum and minimum temperature and relative humidity compared to normal during the cropping period. The total annual rainfall during the cropping period of 2021 was 632.8 mm, which was 95.5 mm lesser than the normal of 40 years. The monthly maximum and minimum air temperature data was the highest during April (37.6 ^{0}C) and May (23.4 ^{0}C), respectively.

The experiment was laid out in a split-plot design with three replications consisting of 12 treatment combinations. Treatments included four main plots with sowing windows (D) *viz*., D_1: 1st fortnight of June, D_2: 2nd fortnight of June, D_3: 1st fortnight of July, D_4: 2nd fortnight of July and three subplots with three genotypes (G) *viz*., G_1: TS-3R, G_2: GRG-152 and G_3: GRG-811. The land was prepared to a fine seedbed, and the plots were laid out as per the experiment layout. Staggered sowing was done as per the treatments at different sowing windows by hand dibbling with 1-2 seeds per hill.

The crop was sown by providing recommended spacing of 120 cm inter-row and 20 cm intra-row as per the treatments. Other agronomic practices were followed to raise a crop. The harvested produce from net plots were weighed just before threshing to record pod weight per plot. After that, threshing was done manually. The threshed crop was winnowed and

Table 1. Plant height at different phenological stages of pigeonpea genotypes as influenced by the growing environments

Treatments	Plant height (cm)			
	Initiation of primary branch (S_2)	Initiation of secondary branch (S_3)	50% flowering (S_5)	Physiological maturity (S_7)
Sowing window (D)				
D_1: 1st fortnight June	52.8	91.1	178.6	196.3
D_2: 2nd fortnight June	51.7	87.0	171.8	189.2
D_3: 1st fortnight July	47.1	81.3	162.6	179.4
D_4: 2nd fortnight July	44.1	74.7	150.6	155.2
S.Em±	0.8	2.2	2.0	4.0
C.D. (p=0.05)	2.8	7.6	7.0	13.8
Genotype (G)				
G_1: TS-3R	47.0	77.3	159.5	169.5
G_2: GRG-152	50.0	86.9	173.5	189.0
G_3: GRG-811	49.9	86.4	164.8	181.6
S.Em±	0.7	1.1	2.1	0.9
C.D. (p=0.05)	2.0	3.2	6.4	2.6
Interactions (D × G)				
D_1G_1	50.2	87.3	174.9	186.8
D_1G_2	54.2	93.2	182.6	204.1
D_1G_3	54.1	92.7	178.3	198.1
D_2G_1	49.9	84.2	169.9	181.5
D_2G_2	52.6	88.7	173.7	195.1
D_2G_3	52.5	88.0	171.9	191.0
D_3G_1	45.6	74.6	153.7	168.5
D_3G_2	47.8	85.5	168.1	188.5
D_3G_3	47.8	83.8	166.1	181.1
D_4G_1	42.1	62.9	139.4	141.2
D_4G_2	45.2	80.2	169.5	168.2
D_4G_3	45.1	81.1	142.9	156.2
S.Em±	1.4	2.1	4.3	1.7
C.D. (p=0.05)	NS	6.4	12.8	5.2

NS: Non significant

cleaned and grain and straw yield were expressed in kilogram per hectare. The harvest index was calculated by using the formula given below as suggested by Donald (1962). The yield attributes and yield were recorded from the net plots and grain yield was converted to hectare basis in kilograms.

$$HI = \frac{\text{Economic yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}} \times 100$$

The correlation studies of growth and yield parameters were carried out in pigeonpea with the help of methodology described by Gomez and Gomez (1984). The level of significance used for 'F' tests was p=0.05 and p=0.01. Critical Difference (CD) values were calculated at a 5% probability level if the F tests were significant. The growth parameter used for correlation studies are plant height, number of primary branches and secondary branches per plant and yield parameters *viz*., total number of pods, seed weight per plant, 100-seed weight, seed yield, straw yield and harvest index.

Results and discussion

Growth and yield attributing characters

Effect of sowing windows

The plant height of pigeonpea was significantly affected by change in sowing windows at different phenological stages *viz*., the initiation of primary branch (S_2), secondary branch (S_3), 50% flowering (S_5) and physiological maturity (S_7) stages. The data presented in Table 1 revealed that sowing in 1st fortnight of June recorded significantly greater plant height (52.8, 91.1, 178.6 and 196.3 cm, respectively) at S_2, S_3, S_5 and S_7 stages than other sowing windows and which was on par with 2nd fortnight of June sowing at S_3, S_5 and S_7 (87.0, 171.8 and 189.2 cm, respectively). Increased plant height of pigeonpea in 1st fortnight of June due to must be favourable long growing season with more soil moisture and nutrients availability because that plant absorbed more moisture and nutrients from the soil, which reflected in cell elongation. These results are in consonance with the findings of Hammerton (1976), Kumar *et al.* (2008), Egbe and Kalu (2012) and Kithan *et al.* (2020) in pigeonpea. A significantly higher number of primary branches plant^{-1} were recorded with sowing under 1st fortnight of June at S_3, S_5 and S_7 stages (8.77, 13.27 and 14.00, respectively) and branches were decreased with delay in the sowing, but statistically at par with the 2nd fortnight of June sowing (8.41, 12.95 and 13.67, respectively). Similarly, a significantly maximum number of secondary branches plant^{-1} was recorded at all stages (4.47, 15.57 and 18.21, respectively) and decreased with delay in sowing while this was on par (4.44, 14.99 and 17.87, respectively) with 2nd fortnight of June sowing. On the other

Table 2. Primary and secondary branches per plant at different phenological stages of pigeonpea genotypes as influenced by the growing environments

Treatments	Primary branches plant^{-1}			Secondary branches plant^{-1}		
	Initiation of secondary branch (S_3)	50% flowering (S_5)	Physiological maturity (S_7)	Initiation of secondary branch (S_3)	50% flowering (S_5)	Physiological maturity (S_7)
Sowing window (D)						
D_1: 1st fortnight June	8.77	13.27	14.00	4.47	15.57	18.21
D_2: 2nd fortnight June	8.41	12.95	13.67	4.44	14.99	17.87
D_3: 1st fortnight July	7.30	11.35	11.89	3.71	13.25	16.09
D_4: 2nd fortnight July	6.80	10.20	11.10	2.74	11.84	15.21
S.Em±	0.13	0.23	0.33	0.07	0.23	0.13
C.D. (p=0.05)	0.45	0.80	1.13	0.25	0.81	0.46
Genotype (G)						
G_1: TS-3R	8.18	12.57	13.13	4.02	14.27	17.07
G_2: GRG-152	7.89	12.17	12.50	3.79	13.83	16.94
G_3: GRG-811	7.38	11.09	12.36	3.72	13.63	16.53
S.Em±	0.11	0.21	0.19	0.06	0.16	0.12
C.D. (p=0.05)	0.33	0.62	0.57	0.17	0.47	0.35
Interactions (D × G)						
D_1G_1	9.10	13.24	13.82	4.40	14.61	17.79
D_1G_2	8.80	13.83	14.33	4.60	16.15	18.43
D_1G_3	8.40	12.73	13.84	4.41	15.96	18.40
D_2G_1	8.99	14.35	14.78	4.78	16.36	18.53
D_2G_2	8.63	12.31	13.67	4.28	14.32	17.64
D_2G_3	7.60	12.18	12.57	4.26	14.30	17.43
D_3G_1	7.47	11.41	12.41	4.09	13.31	16.53
D_3G_2	7.33	11.33	11.73	3.53	13.23	16.26
D_3G_3	7.09	11.29	11.52	3.51	13.20	15.48
D_4G_1	7.15	11.26	11.50	2.81	12.81	15.43
D_4G_2	6.80	11.19	11.52	2.74	11.63	15.40
D_4G_3	6.44	8.14	10.27	2.68	11.07	14.80
S.Em±	0.22	0.42	0.38	0.12	0.32	0.23
C.D. (p=0.05)	NS	1.25	1.13	0.35	0.95	0.70

NS: Non significant

Table 3. Yield and yield parameters of pigeonpea genotypes as influenced by the growing environments

Treatments	Healthy pods	Damaged pods	% pod damage	Total no. of pods plant^{-1}(g)	Seed weight (g)	100-seed weight (g)
Sowing window (D)						
D_1: 1st fortnight June	97.5	20.1	16.89	117.7	53.1	12.5
D_2: 2nd fortnight June	96.2	21.2	18.30	116.2	52.9	12.1
D_3: 1st fortnight July	80.1	31.6	28.55	111.7	47.2	11.0
D_4: 2nd fortnight July	71.3	31.0	30.28	101.3	42.2	10.8
S.Em±	1.7	0.5	0.50	2.0	0.8	0.2
C.D. (p=0.05)	5.7	1.8	1.72	6.9	2.7	0.7
Genotype (G)						
G_1: TS-3R	89.5	29.3	24.94	118.3	50.2	11.9
G_2: GRG-152	85.8	22.3	20.38	110.6	49.8	11.5
G_3: GRG-811	83.6	26.3	25.20	106.3	46.5	11.4
S.Em±	0.9	0.4	0.32	1.2	0.7	0.2
C.D. (p=0.05)	2.6	1.1	0.95	3.6	2.0	NS
Interactions (D × G)						
D_1G_1	95.1	29.1	23.42	124.2	53.1	12.7
D_1G_2	100.1	13.5	11.78	114.6	53.8	12.2
D_1G_3	97.4	17.7	15.47	114.4	52.2	12.4
D_2G_1	102.5	19.5	16.25	120.0	54.3	12.4
D_2G_2	93.7	21.9	19.09	114.7	52.5	12.1
D_2G_3	92.5	22.3	19.56	114.0	51.8	11.8
D_3G_1	88.5	27.5	23.70	116.0	48.3	11.2
D_3G_2	76.5	28.7	24.95	115.0	47.3	10.9
D_3G_3	75.3	38.5	37.01	104.0	46.0	10.8
D_4G_1	71.9	41.1	36.37	113.0	45.0	11.3
D_4G_2	72.8	25.2	25.71	98.0	45.5	10.6
D_4G_3	69.3	26.7	28.77	92.8	36.0	10.5
S.Em±	1.8	0.7	0.63	2.4	1.3	0.4
C.D. (p=0.05)	5.3	2.1	1.89	7.2	4.0	NS

NS: Non significant

hand, a significantly minimum number of secondary branches plant^{-1} in 2nd fortnight of July sowing was observed in Table 2. Similar results were reported by Kithan *et al*. (2020) and Kumar *et al*. (2008).

The yield and yield parameters varied significantly due to different sowing windows (Table 3 and 4). Among the different sowing windows, sowing in 1st fortnight of June registered a significantly higher number of healthy pods plant^{-1} (97.5), which was on par with the 2nd fortnight of June sowing (96.2). The minimum number of healthy pods plant^{-1} (71.3) was recorded under the 2nd fortnight of July sowing. On the other hand, the minimum number of damaged pods plant^{-1} (20.1) was recorded under the 1st fortnight of July sowing, followed by the 2nd fortnight of June sowing (21.2). However, sowing in 2nd fortnight of July recorded a significantly higher number of damaged pods plant^{-1} (31.6), which was on par with the 2nd fortnight of July sowing (31.0). The pigeonpea crop sown in 1st fortnight of June observed a lesser % pod damaged plant^{-1} (D_1, 16.89), followed by 2nd fortnight of June sowing (D_2, 18.30). However, the % pod damage was greater in 2nd fortnight of July sowing (30.28). Whereas pigeonpea sown in 1st fortnight of June recorded a significantly higher number of total pods plant^{-1} (117.7), which was on par with the 2nd fortnight of June (116.2) and 1st fortnight of July sowing (111.7). The maximum total pod number in early sown pigeonpea plants was mainly due to a significant increase in the number of branches, which was attributed to better resource availability, including more rainfall. These results are in line with the findings of Ram *et al*. (2011) in pigeonpea. Whereas delaying the sowing from the 1st fortnight of June to the 2nd fortnight of July reduced the seed weight from 53.1 to 42.2 g plant^{-1}. Significantly higher seed weight (53.1 g plant^{-1}) was recorded under the early sowing in 1st fortnight of June, which was statistically akin with 2nd fortnight of June (52.9 g plant^{-1}). The test weight or 100-seed weight is an important character in pigeonpea. Pigeonpea sown in 1st fortnight of June received sufficient moisture and nutrients, and their efficient utilization in source to shrink relationship is reflected in more 100-seed weight. It recorded a significantly higher test weight (12.5 g), which was on par with the 2nd fortnight of June sowing (12.1 g). These results are in the same line as Salih (1990). Seed yield is governed by several factors that have a direct or indirect impact. Among the yield components, pod and seed yield per plant was more closely related to seed yield. In the present study, the pigeonpea sown in 1st fortnight of June produced significantly higher seed yields (1539 kg ha^{-1}), which was closely followed by and statistically at par with 2nd fortnight of June sowing (1535 kg ha^{-1}). It was observed that each consecutive 15 days delay in the sowing from 1st fortnight of June caused a significant yield reduction by 10.01% under 1st fortnight of July (1385 kg ha^{-1}) and 23.61% under 2nd fortnight of July sowing (1191 kg ha^{-1}). The increased seed yield due to early sowings is ascribed to the high LAI and its persistence, branches, PAR interception and absorption, leading to higher dry matter

Table 4. Yield and harvest index of pigeonpea genotypes as influenced by the growing environments

Treatments	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
Sowing window (D)				
D_1: 1st fortnight June	1539	4326	5865	26.21
D_2: 2nd fortnight June	1535	3932	5464	28.08
D_3: 1st fortnight July	1385	3238	4623	30.03
D_4: 2nd fortnight July	1191	2528	3718	32.08
S.Em±	56	112	148	0.87
C.D. (*p=0.05*)	194	388	514	3.01
Genotype (G)				
G_1: TS-3R	1455	3402	4854	30.61
G_2: GRG-152	1424	3570	4994	28.84
G_3: GRG-811	1358	3546	4904	27.86
S.Em±	16	41	37	0.47
C.D. (*p=0.05*)	47	121	110	1.42
Interactions (D × G)				
D_1G_1	1537	4305	5842	26.24
D_1G_2	1542	4347	5889	26.15
D_1G_3	1539	4326	5865	26.24
D_2G_1	1550	3909	5450	28.41
D_2G_2	1529	3948	5477	27.90
D_2G_3	1525	3940	5464	27.93
D_3G_1	1410	2900	4310	32.72
D_3G_2	1399	3414	4813	29.04
D_3G_3	1345	3400	4745	28.34
D_4G_1	1322	2493	3815	35.05
D_4G_2	1225	2571	3796	32.05
D_4G_3	1025	2519	3543	28.91
S.Em±	32	81	73	0.95
C.D. (*p=0.05*)	95	243	220	NS

accumulation before the crop reaches the reproductive stage (Patel *et al.,* 2000). Under late sown, the plant could not accumulate sufficient photosynthates due to the short vegetative growth period, hence less strong sink *i.e*., the number of pods plant^{-1}, which was also reported by Singh *et al.* (2012) in black gram. A significantly higher straw yield was also observed with early sowing in the 1st fortnight of June (4326 kg ha^{-1}). As the sowing was delayed, the reduction in straw yield in the 2nd fortnight of July occurred mainly due to the decreased growth attributes of leaf area, plant height and number of branches. The straw yield decreased to 25.15% and 41.56% in delayed sowings 1st fortnight and 2nd fortnight of July (3238 and 2528 kg ha^{-1}, respectively) over the 1st fortnight of June sowing (4326 kg ha^{-1}). The slower growth on the account of lower temperature during the early vegetative growth phase and the overall shorter life span of the crop caused a plant's biomass reduction. The higher biological yield in 1st fortnight of June sowing may be due to more dry matter production, which was reflected in a lesser harvest index (26.21%) compared to 2nd fortnight of July sowing (32.08%), indicating low efficiency of dry matter distribution into reproductive parts. The results corroborate with the findings of Arunkumar *et al*. (2014) and Kithan *et al.* (2020) in the pigeonpea crop.

Effect of genotypes

The plant height of pigeonpea varied significantly at different phenological stages, *viz*., the initiation of primary branch (S_2), secondary branch (S_3), 50% flowering (S_5) and physiological maturity (S_7) stages as influenced by pigeonpea genotypes are presented in Table 1. The genotype GRG-152 recorded significantly higher plant height (50.0, 86.9, 173.5 and 189.0 cm, respectively) at S_2, S_3, S_5 and S_7 stages than the other genotypes, which was at par with GRG-811 at S_2 and S_3 stages (49.9 and 86.4 cm, respectively). The genotype TS-3R recorded a significantly higher number of primary branches at all stages (8.18, 12.57, and 13.13, respectively), but it was on par with GRG-152 (7.89 and 12.17, respectively) at S_5 and S_7. At all the stages, genotype TS-3R sown under 1st fortnight of June recorded a significantly higher number of secondary branches plant^{-1} (4.02, 14.27 and 17.07, respectively), which was on par with GRG-152 (13.82 and 16.94, respectively) at S_5 and S_7. While GRG-811 observed a minimum number of secondary branches plant^{-1} (3.72, 13.63 and 16.53, respectively) at all the stages (Table 2). The dominant growth habit of pigeonpea genotype TS-3R reflected luxurious growth in terms of number of branches plant^{-1} than other genotypes as it has a more inherent capacity for efficient moisture and nutrient utilization. These results are in agreement with Chauhan (1990) in pigeonpea.

The genotypes differ significantly for the number of pods, seed weight plant^{-1} and 100-seed weight, seed yield, straw yield, biological yield and harvest index. Among the genotypes, a significantly maximum number of healthy pods (89.5) were recorded by genotype TS-3R and the minimum values (83.6) were recorded by genotype GRG-811. A significantly maximum number of damaged pods plant^{-1} (29.3) was recorded by genotype TS-3R, followed by GRG-811 (26.3) and GRG-152 (22.3). However, minimum % pod damage was recorded by the genotype GRG-152 (22.3). Where TS-3R produced a higher total number of pods plant^{-1}, seed weight plant^{-1}and 100-seed weight (118.3, 50.20 g and 11.9 g, respectively) followed by the other two genotypes, GRG-152 (110.6, 49.8 g and 11.5 g, respectively) and GRG 811 (106.3, 46.5 g and 11.4 g, respectively). The decrease in yield attributing characters of GRG-811 is due to fewer pods, seed weight and 100-seed weight (Table 3). Thus, owing to the integration of all the favorable yield components, such as a relatively greater number of pods plant^{-1}, seeds weight plant^{-1} and 100-seed weight in TS-3R, produced significantly higher seed yield compared to the rest of the genotypes (Table 3). Kithan *et al.* (2020) and Behera (2018) also noticed this variation among the genotypes. The pigeonpea genotype TS-3R noted significantly higher seed yield (1455 kg ha^{-1}) than that of GRG-152 (1424 kg h^{-1}) and GRG-811 (1358 kg ha^{-1}). The genotypes TS-3R utilized favourably soil moisture and nutrients as well as more light absorption, lower leaf temperature exhibited higher magnitude of growth and yield attributes which reflected in achieving in higher grain yield (Table 4). The results are in conformation with the findings of Salih (1990) and Singh *et al.* (2010). On the contrary, straw yield were higher in GRG-152 (4994 kg ha^{-1}) than in other genotype. The improvement in straw yield might be due to higher biomass production and its distribution in different plant parts in GRG-152 compared to other genotypes. The genotypic variation for straw yield was also noticed and reported by Niveditha *et al.* (2022) in chickpea. The higher biological yield in GRG-152 may be due to tall plants and more total dry matter production, resulting in a low harvest index (28.84%) than TS-3R (30.61%), indicating low efficiency of the total dry matter distribution in reproductive parts. Genotypes are different in their yield potential depending on many complex physiological processes in different parts of the plant, which are controlled by both the plant's genetic makeup and the environment (Tigga *et al.*, 2017).

Interaction effect

The interaction of sowing windows and pigeonpea genotypes differed significantly for crop growth and yield parameters. The genotype GRG-152 sown in 1st fortnight of June recorded a greater plant height (93.2, 182.6 and 204.1 cm, respectively) at S_3, S_5 and S_7, which was on par with GRG-811 sown in 1st fortnight of June (92.7 cm), GRG-152 sown in 2nd fortnight of June (88.7 cm), GRG-811 sown in 2nd fortnight of June (88.0 cm) and TS-3R sown in 1st fortnight of June

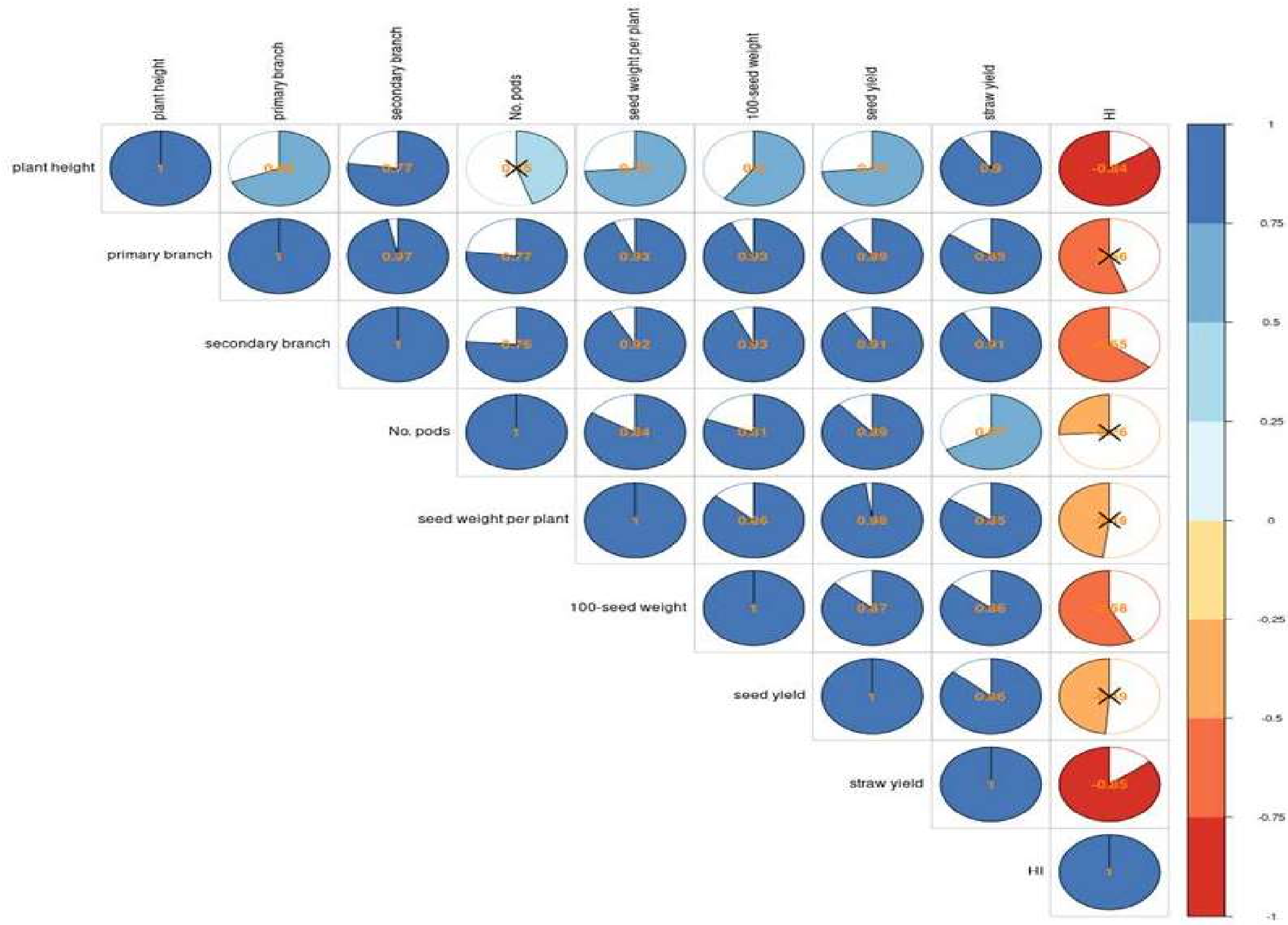

Fig1. Correlation matrix of various growth and yield attributes of pigeonpea genotypes under different growing environments

(87.3 cm) at S_3, GRG-811 sown in 1st fortnight of June (178.3 cm), TS-3R sown in 1st fortnight of June (174.9 cm), GRG-152 sown in 2nd fortnight of June (173.7 cm), GRG-811 sown in 2nd fortnight of June (171.9 cm) at S_5 (Table 1). The genotype TS-3R sown in 2nd fortnight of June recorded a significantly higher number of primary branches plant^{-1} at S_5 and S_7 (14.35 and 14.78, respectively), which was on par with GRG-152 sown in 1st fortnight of June (13.83) and TS-3R sown in 1st fortnight of June (13.24) at S_5, GRG-152 sown in 1st fortnight of June (14.33), GRG-811 sown in 1st fortnight of June (13.84), TS-3R sown in 1st fortnight of June (13.82) and GRG-152 sown in 2nd fortnight of June (13.67) at S_7. The genotype TS-3R sown in the 2nd fortnight of June recorded a significantly higher number of secondary branches plant^{-1} at S_3, S_5 and S_7 (4.78, 16.36 and 18.53, respectively), which was on par with GRG-152 and GRG-811 sown in 1st fortnight of June (Table 2).

Among the interactions, the genotype TS-3R sown in the 2nd fortnight of June recorded a significantly higher number of healthy pods plant^{-1} (102.5), which was on par with GRG-152 sown in 1st fortnight of June (100.1) and GRG-811 sown in 1st fortnight of June (97.4). The fewer damaged pods plant^{-1} was recorded with genotype GRG-152 sown in 1st fortnight of June (13.5). However, % pod damage was lesser in the interaction of GRG-152 sown in 1st fortnight of June (11.78). A significantly higher total number of pods plant^{-1} and seed weight was recorded by the genotype TS-3R sown in 2nd fortnight of June (120.0 and 54.3 g, respectively). This result is closely related to the findings of Behera *et al.* (2018) in pigeonpea. The interaction of sowing windows and pigeonpea genotypes differed significantly for crop growth and yield parameters. The pigeonpea genotype TS-3R sown in 2nd fortnight of June recorded a significantly higher seed yield (1550 kg ha^{-1}), which was on par with the interaction of GRG-152 sown in 1st fortnight of June (1542 kg ha^{-1}), GRG-811 sown in 1st fortnight of June (1539 kg ha^{-1}), TS-3R sown in 1st fortnight of June (1537 kg ha^{-1}), GRG-152 sown in 2nd fortnight of June (1529 kg ha^{-1}) and GRG-811 sown in 2nd fortnight of June (1525 kg ha^{-1}), while the reduction in yield seen in delayed sown condition *i.e.*, 2nd fortnight of July with the genotype GRG-811 (1025 kg ha^{-1}). However, higher straw yield was recorded by the interaction of GRG-152 sown in 1st fortnight of June (4347 kg ha^{-1}) while reduction in straw yield in the interaction TS-3R sown in 2nd fortnight of July (2493 kg ha^{-1}). Similarly, lower harvest index 26.15 % was observed in the interaction of GRG-811 sown in 1st fortnight of June sowing (Table 3). This may be due to variables like higher primary branches, number of pods plant^{-1}, which facilitated higher seed yield. A significant interaction was found due to sowing windows and genotype, which influenced the plant height, number of pods plant^{-1}, pod weight, grain and haulm yield indicating the genotype performed better at different planting periods (Egbe *et al.*, 2013).

Correlation studies

The correlation matrix between growth and yield parameter are presented in Fig. 1. Seed yield was positively correlated with plant height (r=0.74), primary branch (r=0.89), secondary branch (r=0.91), number of pods (r=0.89), seed weight (r=0.98), 100-seed weight (r=0.87), straw yield (r=0.86). It showed non significantly negative correlation with the harvest index (r=-0.49). Similar correlation results are found by Niveditha *et al.*, 2022.

Conclusion

It is concluded from the data that pigeonpea sown in 1st fortnight of June performed best for growth and yield attributes. Among the genotypes, TS-3R performed the best under early sown in 1st fortnight of June. However, GRG-152 and GRG-811 also performed better under early sown conditions compared to delayed sowings in July in the northern dry zone of Karnataka.

References

Ahlawat I P S and Rana D S, 2005, Concept of efficient water use in pulses. *Agrotech Publishing Academy*, Udaipur, India, 6(1): 313-340.

Arunkumar, 2014, Phenological behavior and productivity of pigeonpea (*Cajanus cajan* L. Millsp.). *M.Sc. (Agri.) Thesis*, University of Agricultural Sciences, Raichur, Karnataka, India.

Behera B, 2018, Response of pigeonpea genotypes to different growing environment under dryland condition. *M.Sc. (Agri.) Thesis,* University of Agricultural Sciences, Dharwad, Karnataka, India.

Chauhan Y S, 1990, Pigeonpea optimum agronomic management. University Press Cambridge, : 257-278.

Donald C M, 1962, In search of yield. *Journal of the Australian Institute of Agricultural Sci*ence, 32 (1&2): 92-93.

Egbe O M and Kalu B A, 2012, Effect of planting dates of pigeonpea in southern Guinea Savanna of Nigeria. *ARPN Journal of Agricultural and Biological Science*,4(1):203-212.

Egbe M O, Aku A A and Odebiyi S, 2013, Effect of planting dates on the performance of pigeon pea varieties in Southern Guinea Savanna ecology of Nigeria. *Journal of Biology, Agriculture and Healthcare,* 3(8): 22-28.

Gomez K A and Gomez A A, 1984, *Statistical Procedure for Agricultural Research,* An International Rice Research Institute Book, Willy Inter Science Publication, New York, USA, 680.

Hammerton J L, 1976, Effects of planting date on growth and yield of pigeon pea (*Cajanus cajan* (L.) Millsp.). *Journal of Agricultural Sciences*, 87: 649-660.

Indiastat, 2021, Selected state-wise area, production and productivity of pigeonpea in India, Ministry of Agriculture and Farmers welfare, Government of India. https://www.indiastat.com.

Kithan L, Sharma M B and Longchar A, 2020, Effect of planting dates on the performance of promising pigeonpea genotype under NEHZ. *International Journal of Economical Plants,* 7(1): 006-008.

Kumar N, Gopinath K A, Srivastva A K and Mahajan V, 2008, Performance of pigeonpea (*Cajanus cajan* L. Millisp.) at different sowing dates in the mid-hills of Indian Himalaya. *Archives of Agronomy and Soil Science,*54(5):507-514.

Nagarajaiah K M, Palled Y B, Patel B N and Khot A B, 2005, Response of chickpea varieties to seed rate and time of sowing under late sown conditions in Malaprabha command Area. *Karnataka Journal of Agricultural Sciences,* 18 (3): 609-612.

Niveditha M P, Patil S B, Kalaghatagi S B and Ashvathama V H, 2022, Growth and yield of chickpea genotypes under changing weather scenario in the Northern Dry Zone of Karnataka. *Journal of Farm Sciences,* 35(2): 192-198.

Patel N R, Mehta A N and Shekh A M, 2000, Radiation absorption, growth and yield of pigeonpea cultivars as influenced by sowing dates. *Experimental Agriculture,* 36: 291-301.

Ram H, Singh G, Sekhon H S and Kanna V, 2011, effect of sowing time on performance of pigeonpea genotype. *Journal of Food Legumes*, 24(3): 207-210.

Reddy M M, Padmaja B and Malathi S, 2012, Evaluation of pigeonpea genotypes for delayed sowing in Telangana region of Andhra Pradesh under rainfed conditions. *Indian Journal of Dryland Agricultural Research and Development,* 27(1): 2231-6701.

Salih F A, 1990, Effect of sowing date and cultivar on grain yield and yield components of pigeonpea in northern part of Sudan. *Pigeonpea Newsletter,* 28-30.

Singh R S, 2006, Performance of late duration pigeonpea varieties under delayed planting. *Indian Journal of Pulses Research,* 19: 255-256.

Singh A K, Singh S B, Singh A P and Singh V, 2010, Influence of sowing time on growth and yield of chickpea genotypes in hilly region of Jammu. *Journal of Food Legumes*, 23(3): 223-225.

Singh G, Ram H, Sekhon H S, Gill K K and Khanna V, 2012, Effect of time of planting on nodulation, growth and seed yield of *kharif* urid bean genotypes. *Journal of Food Legumes*, 25(2):125-127.

Singh G, Kaur H, Aggarwal N, Ram H, Gill K K and Khanna V, 2017, Symbiotic characters, thermal requirements, growth, yield and economics of pigeonpea (*Cajanus cajan*) genotypes sown at different dates under Punjab conditions. *Journal of Applied and Natural Sciences,* 8(1): 381-385

Thimmegowda P, Hallikatti S I, Venkatesh H, Hiremath S M and Aravindkumar N, 2013, Phenology, thermal time and phasic development of pigeonpea (*Cajanus cajan* L. Millisp.) grown under intercropping system. *Journal of Agrometeorology*, 15 (Special Issue - II): 29-134.

Tigga B, Chandraker D K, Banjara T R, Bhagat S K and Dev M, 2017, Effect of different genotype and planting geometry on growth and productivity of *rabi* season pigeon pea (*Cajanus cajan* L.). *International Journal of Current Microbiology and Applied Sciences,*6(3): 2188-2195.