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Optimizing Cowpea Productivity by Sowing Date and Plant Density to Mitigate Climatic Changes

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ADAPTATION to climatic changes by adjusting sowing date and using the optimum planting density can mitigate the negative effects on cowpea productivity. A field experiment was performed during two growing seasons of 2019 and 2020 at the experimental farm of Kafr Al-Hamam Agric. Res. Station, Sharqia Governorate, Egypt. The study aimed to optimize sowing date (31 May, 15 June and 30 June) and planting density (285715, 142860, 95240, 71430 and 57145 plants ha^{-1}) that perform better in terms of seed and biomass yields as well as seed quality of cowpea under semi-arid conditions. The late cowpea sowing on 30 June appeared to be produced the higher seed yield contributions and yields ha^{-1}, crop and harvest index as well as pure seed. In respect of sowing density, intermediate planting density (95240 plants ha^{-1}) exhibited the higher seed yield components and yields ha^{-1}, crop and harvest index as well as pure seed. Results of interaction indicated that late sowing on 30 June attained the maximum seed yield when intermediate planting density of 95240 plants ha^{-1} was used. Late sowing under lighter (57145 and 71430 plants ha^{-1}) and intermediate (95240 plants ha^{-1}) planting densities exhibited the highest pure seed as well as the fewest shriveled and infected seeds. Path coefficient analysis showed that number of pods plant^{-1} had exerted positive and high direct effect on seed yield of cowpea (0.385) and 100-seed weight had positive and moderate direct effect on seed yield of cowpea (0.251).

Keyword: Cowpea, Path analysis, Planting density, Seed quality, Sowing date.

Introduction

Among seed legumes, cowpea (*Vigna unguiculata* L.) is an important multipurpose legumes crop in semi-arid regions of the tropical and subtropical areas because of its protein content (20-25%), carbohydrates (63.3%), iron (48.69 mg kg^{-1}), zinc (29.9-41.8mg kg^{-1}), fiber (6.3%) and fat (1.9%) (Davis, 1991; Silva et al., 2014), and the essential amino acid lysine (Hafiz & Damarany, 2006). Also, the leaves and fresh pods provide a low cost source of vitamins and minerals. In addition, it is grown for its nutritious fodder for livestock, green manure crop, mulch crop, hay crop, intercrop and can be used as a trap crop. It is characterized by its great ecological diversity and adapted to high temperatures as well as it grows well in a wide range of soil texture that makes it proficient as a good cover crop and soil fertility enhancer and has rapid and luxuriant vegetative growth (Elawad, 2000; Hector & Jody, 2002; Kumar et al., 2008; Agbicodo et al., 2009; Hall, 2012; Oyewale & Bamaiyi, 2013; Giridhar et al., 2020). In addition, it has the ability to fix atmospheric nitrogen in soil at the rate of 40-80kg per ha (Mafakheri et al., 2017). The total area under cultivated of cowpea plant in Egypt was estimated at 1853 ha with a mean production of 7180 tons of dry seeds (FAOSTAT, 2021). This clearly indicates the necessity for research to improve cowpea productivity in Egypt. The changes in climate factors are being felt globally in the form of changes in temperature. An increase in ambient CO_2 is usually considered beneficial as it results

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in increased photosynthesis in crops, especially those with C_3 mechanism of photosynthesis as cowpea crop. Sowing date is one of the most important agricultural practices that determine legumes crops productivity especially cowpea.

Asante et al. (2001) reported that sowing date has a great impact on seed yield and quality of cowpea and effectively reduced the menace of insect pest damage on cowpea pods and invariably increased grain yield. Also, Mobbaser et al. (2006) investigated that the highest seed yield belonged to sowing date of April 30. Early sowing has reportedly enabled cowpea to escape high temperatures during the flowering stages so, gave the best yields and reduced infestation of insects (Karungi et al., 2001; Hall, 2012; Abudulai et al., 2017). Compared to July first fortnight and July second fortnight sowing, significantly higher growth parameters, seed yield and HI were recorded in cowpea sown in June second fortnight, but time of sowing did not significantly influence the seed quality parameters (Taipodia & Nabam, 2013). Mojaddam & Nouri (2014) investigated that the highest seed yield and its components in terms of sowing date was related to July 23 and the lowest one was related to July 6. In addition, sowing at optimum time enables the crop to best use the available growth factors such as temperature and solar radiation at different stages of growth for high productivity (Togay et al., 2014). Sowing date is one of the important agronomic practices that lead to the greatest differences in growth, the quantitative and qualitative paramters of crop without involving additional costs such as using insecticides (Nwofia et al., 2018). Moreover, Nwofia et al. (2018) reported that cowpea planted in August gave higher grain yield relative to the other planting dates (July and September). Furthermore, Hasanzadeh et al. (2019) showed that the uppermost seed yield and seed protein content were recorded by sowing cowpea on 15 June compared to sowing on 20 May. Additionally, sowing cowpea in early April is appropriate for significantly improve final crop yields (Nunes et al., 2021).

On other side, cowpea plants are one of non-dense growing crops so, planting density is a very important agronomic practices that determine the productivity of cowpea and are particularly affected by sowing date and genotypes. Adjusting planting density is an important tool to optimize crop growth and to achieve maximum biomass and grain yield (Liu et al., 2008; Kamara et al., 2014; Giridhar et al., 2020). Several authors reported significant differences of seed yield, yield attributes and quality due to varying planting densities of cowpea. Early, Ayaz et al. (2001) and Hayat et al. (2003) reported that the number of seeds in legumes pods changed as plant density changed and increase of density led to decrease of number of seeds per pod. Moreover, Liu et al. (2008), El Naim & Jabereldar (2010) and Bruns (2011) reported that increased plant density significantly increased the growth attributes, seed yield, however the number of pods per plant, 100-seed weight and HI reduced with increased plant density. While, Taipodia & Nabam (2013) showed that growth, yield and seed quality of cowpea were not significantly influenced by the seed rate. Kanteh el al. (2014) reported that the best choice for insect pests control in cowpea is wider plant spacing than at closer spacing. Moreover, Mojaddam & Nouri (2014) showed that density of 31plants/m^2 had the greatest number of pods per plant, number of seeds per plant, 100-seed weight, seed yield, biomass yield and HI. Kamara et al. (2014) and Giridhar et al. (2020) reported that high plant density increases crop performance in terms of light interception, biomass production, yield and yield components (pods and seeds) for cowpea. On other hand, correlation simply measures that mutual relationship between yield and yield components. Path analysis provides information about magnitude and direction of direct and indirect effect of the yield contributions, which cannot be provided by correlation (Bizeti et al., 2004; Chaudhary & Joshi, 2005). The present research was intended to determine the optimum planting density for cowpea by inter-hills spacing that achieves the minimal inter and intra-specific competition to maximize seed yield and seed quality of cowpea. In addition, to determine the appropriate sowing date for higher seed production and quality of cowpea due to change in agro-climatic conditions, so periodic evaluation of planting dates is of urgent need.

Materials and Methods

Experimental site

A field experiment was conducted for two successive summer seasons (2019 and 2020) at the experimental farm of Kafr Al-Hamam Agricultural Research Station at Sharqia Governorate, Egypt (30° 36› 49» N, 31° 30› 56» E). Soil samples were taken from the sites at a depth of 0-60cm before sowing cowpea (*Vigna unguiculata* L. cv. Baladi) in both seasons to determine soil physical and chemical properties (Table 1) according to Black & Hartge (1968). Moreover, meteorological data during the growing seasons are presented in Table 2.

TABLE 1. Physical and chemical analyses of the experimental sites in 2019 and 2020 growing seasons

Soil characteristics	2019	2020
Soil particles distribution		
Sand (%)	18.55	14.83
Silt (%)	26.80	28.95
Clay (%)	54.65	56.22
Texture class	Clay	Clay
Chemical properties		
pH*	7.90	7.85
Electrical conductivity(dS m^{-1})**	2.30	2.32
Organic matter (%)	1.42	1.20
Available nutrient (mg kg^{-1} soil)		
Nitrogen (N)	25.40	22.06
Phosphorus (P)	18.00	16,4
Potassium (K)	380.4	368.2

*: Soil-water suspension 1: 2.5, **: Soil water extract 1: 1

Experimental design and agronomic practices

The experimental design was a split plot with three replications. The main plots were randomly occupied by three sowing dates (31 May, 15 June and 30 June) and five planting densities, i.e., D1, 285715; D2, 142860; D3, 95240; D4, 71430; D5, 57145 plants ha^{-1}, corresponding to spacing intervals among hills, i.e., 70×10cm^2, 70×20cm^2, 70×30cm^2, 70×40cm^2 and 70×50cm^2 were randomly applied in the sub plots, with 1.0m spacing. The sowing dates plots were separated by an alley of 2m. Each sub plot (3.5m×3m) consisted of 5 ridges with 0.7m spacing between ridges. On all ridges, each hill was received three seeds, which were thinned to two seedlings per hill at full emergence. The preceding crop was wheat (*Triticum aestivum* L.) in both seasons. Before sowing, 75kg P_2O_5 ha^{-1} as calcium superphosphate (15.5% P_2O_5) and 70kg K_2O ha^{-1} as potassium sulfate (48% K_2O) were added.

Nitrogen fertilization was applied at 40kg N ha^{-1} as ammonium sulfate (21% N) was added once at sowing. All recommended agronomic practices for commercial production of cowpea crop were applied. Harvest was done at the physiological maturity stage.

Growth and yield parameters measurements

At the physiological maturity, ten plants were randomly taken from each plot and tagged for plant height (cm) "from the ground level to the top of the plant", pod length (cm), number of pods $plant^{-1}$, number of seeds pod^{-1}, pods weight $plant^{-1}$ (g), 100-seed weight (g) have been assessed. Both seed yield, fodder yield (hay yield), biological yield, crop index (CI, %) and HI (%) occupying the three middle ridges from each plot were measured within a total area of 6.3 m^2 per plot and then converted per hectare. The final seed yield (kg ha^{-1}) was adjusted to 13% moisture content. For hay yield determination, the harvested plants (stems and leaves) in each plot were rolled up and left on the plot to sun-dry to constant weight and then estimated as hay yield per hectare. Cowpea plants for seed production were not cut for fresh forage to prevent any drop in seed yield and quality especially under late sowing time.

TABLE 2. Monthly average minimum temperature (Min.), maximum temperature (Max.), relative humidity (RH) and total precipitation (Prec.) in 2019 and 2020 growing seasons

Month	2019				2020			
	Min.	Max.	RH.	Prec.	Min.	Max.	RH	Prec.
	---------°C----------		%	mm	---------°C----------		%	mm
May	17.59	35.83	46.41	0.03	15.90	32.17	49.89	0.01
June	21.86	37.75	42.53	0.00	19.37	36.43	42.31	0.00
July	22.83	39.03	42.16	0.00	22.18	39.15	42.75	0.00
August	23.27	39.00	43.29	0.00	22.76	39.26	44.96	0.00
September	21.49	35.61	50.89	0.00	22.76	37.11	50.52	0.00
October	19.52	32.29	57.29	0.47	16.16	31.83	55.04	0.01

Determination of physical purity (quality)

The cowpea seed samples were analyzed for physical purity according to the International Seed Testing Association (ISTA, 2015). Purity test was done on four replicates of 100g each. Each of the samples was separated into pure seed, discolored/shriveled seed and infected seeds on a separating board with the aid of separating knife and magnifying lens. Weight of each fraction was taken, and the percentage of each component was calculated as follows:

Component (%)= (Weight of component (g))/(Total weight of sample (100 g)) x100

Economic analysis

Total costs of applied agricultural practices (land rent, seeds, fertilizers, irrigation, pest management, labor, power and machinery) were calculated. The costs of farm operations were calculated based on the official and the actual market prices determined by the Egyptian Ministry of Agriculture (Economic Reports, 2020). Three economic parameters were estimated: total income (US\$ ha^{-1}), net income (US\$ ha^{-1}) and return invested (US\$). The total income from seed and fodder yields were calculated by multiplying total seed yield and fodder yield ha^{-1} by actual price. Net income from the production of seed and fodder crops were estimated as the difference between total income and total costs. Besides, return on investment was calculated by dividing total income by total cost.

Statistical analysis

The obtained data were analyzed statistically according to procedures outlined by Gomez & Gomez (1984) using MSTAT- C computer software package (1991). Differences found among all treatments; sowing date, planting density, and their interactions were separated by the Least Significant Difference (LSD) at $P\leq 0.05$. Pearson's simple correlation matrix for yield, yield attributes and seed physical purity was also computed by the SPSS 20. The path coefficient analysis was estimated as outlined by Dewey & Lu (1959).

Results and Discussion

Seed yield attributes

Analysis of variance displayed highly significant effects of sowing date, planting density and their interaction on yield attributes of cowpea (Tables 3 and 4). Plant height was significantly impacted by sowing date (Table 3). Early sowing (31 May) had the highest plant height followed by intermediate (15 June) and late sowing (30 June) dates, respectively in both seasons. The increase of plant height due to early sowing clearly indicate that, sowing at optimum time enables the crop to best use the available growth factors such as temperature and solar radiation at different stages of growth. Hall (2012) reported that early sowing has reportedly enabled cowpea to escape high temperatures during the flowering stages when the crop is sensitive to heat. Otherwise, sowing date had no significant effect on pod length in first season. While, in the second season, the longest pod length (17.07 and 18.00cm) was achieved by intermediate and late sowing dates compared to early sowing (15.27cm), respectively. These results are in accordance with those reported by Taipodia & Nabam, (2013), Mojaddam & Nouri (2014) and Nwofia et al. (2018). Number of pods plant^{-1}, number of seeds pod^{-1}, pod weight plant^{-1} and 100-seed weight were an important yield components and has a direct effect on cowpea seed yield. Late sowing date produced significantly the highest number of pods plant^{-1} (19.00 and 16.73), number of seeds pod^{-1} (18.33 and 15.60), pod weight plant^{-1} (28.28 and 32.02g) and 100-seed weight (9.13 and 8.76g) (Tables 3 and 4) compared to early or intermediate sowing dates in the two growing seasons. Late sowing showed significant yield components improvement than intermediate and early sowing dates. The reasons for the lower seed yield components due to earliness in planting, could be expose plants to heat stress during the flowering and pod formation stages as well as seed filling period and it was reflected in the failure of pollination, decrease in number of pods and seeds as well as seed weight. Another reason could be due to cowpea plant is characterized by its great ecological diversity, grown in the warm-season of the tropics and subtropics as well as it has strong adaptation that allows to set seed redeveloping.

Also, the negative impacts of early sowing was more pronounced in pod attributes might be attributed to luxuriant vegetative growth at the expense of the pods attributes. In addition, this might be due to receiving the growing degree day (GDD) requirements at early growth stages which reinforced cowpea plants to hasten maturity. These results are in accordance with those reported by Mojaddam & Nouri (2014), Nwofia et al. (2018) and Hasanzadeh et al. (2019) showing that late sowing resulted in higher yield components of cowpea over early sowing. On the other hand, plant height was significantly depressed under light density compared with other dense ones. Plant height decreased from 137.2 and 140.2cm at dense planting to 108.7 and 111.9cm at light density in the both seasons, respectively. These results refer to a favorable effect caused by increasing the planting density regarding plant elongation. Such dense planting forced plants for more elongation where plants might have had thinner stem diameter as well as cowpea plants might had suffered from paleness and the possible increase of mutual shading and hence performed less regarding their photosynthesis. These results are in accordance with those reported by El Naim & Jabereldar (2010), Bruns (2011), Helmy et al. (2015), Kamara et al. (2014) and Giridhar et al. (2020) reported that increased plant density significantly increased the growth attributes as plant height and increases crop performance in terms of light interception. Besides, the increase in cowpea plant height at the narrow inter-row spacing intervals could be attributed to competition for light and space (Nderi, 2020).

Otherwise, pod length, number of pods plant^{-1}, number of seeds pod^{-1}, pod weight plant^{-1} and 100-seed weight tended to be gradually increased due to intermediate planting density compared with other densities for cowpea (Tables 3 and 4). Such increase in yield components resulted from the optimum planting density (intermediate density) may be due to the decreased intra/ or intra-competition among plants and struggling for the viable nutrients and enables cowpea plants to best use the available growth factors such as water, space, solar radiation at different stages of growth and hence the supply of photoassimlates to the seeds increases. These findings are in consonance with previous studies findings where significantly higher yield attributes were reported under the optimum planting density (Liu et al., 2008; Kamara et al., 2014; Giridhar et al., 2020). Besides, Hayat et al. (2003) reported that the number of seeds in legumes pods changed as plant density changed and increase of density led to decrease of number of seeds per pod. There was significant two-way interaction effects on plant height and yield components (Tables 3 and 4). The longest plants (154.3 and 145.3cm) were assigned for dense planting (D1 and D2) under early sowing date in both seasons, respectively. Whereas the shortest plants (101.0 and 98.0cm) were presented by light planting density (D5) under late sowing date during the two seasons. This may be due to the heat units and metabolites stored in early sowing caused to plant vigorous growth for plants. Otherwise, the highest pod length was assigned for intermediate planting density under intermediate and late sowing dates in both seasons. Furthermore, the uppermost number of pods plant^{-1} (20.67 and 19.00), pod weight plant^{-1} (34.83 and 40.20g) and 100-seed weight (10.41 and 10.68g) were recorded by intermediate planting density under late sowing date during the two growing seasons. In respect of number of seeds pod^{-1}, the results revealed that intermediate sowing exhibited the highest number of seeds pod^{-1} (19.33 and 18.00) followed by late sowing date under intermediate planting density throughout both seasons. Such increase in yield components resulted from the optimum planting density under intermediate or late sowing dates may be due to the decreased specific competition between cowpea plants and adapted to high temperatures (tropical crop) and this can be attributed to the cowpea›s ability to grow in varying environmental conditions. Besides, Giridhar et al. (2020) reported that high population densities may affect light interception, nutrient uptake and water availability of crop especially cowpea plants have rapid and luxuriant vegetative growth.

Yields, CI and HI

Seed, hay, biological yields per ha^{-1}, CI and HI were significantly affected by sowing date, planting density and their interactions (Tables 5 and 6). Seed yield was the result of combined effect for the above-mentioned yield components. Noticeably, sowing date had significant effect on final cowpea seed yield (Table 5). Late sowing (30 June) produced the highest seed yield followed by intermediate (15 June) and early (31 May) sowing date throughout both seasons. The superiority of seed yield ha^{-1}, achieved by late sowing relatively to intermediate and early sowings amount to around 12.7 and 43.2% in the 1st season and amount to around 10.8 and 65.2% in the 2nd season, respectively. These results almost followed the same patterns of the yield components include number of pods plant^{-1} (Table 3), number of seeds pod^{-1}, pod weight plant^{-1} and 100-seed weight (Table 4).

TABLE 3. Plant height (cm), pod length (cm) and number of pods plant^{-1} of cowpea as affected by sowing date and planting densities and their interactions in both seasons.

Sowing date	Plant height (cm)						Pod length (cm)						Number of pods plant^{-1}					
	D1	D2	D3	D4	D5	Mean	D1	D2	D3	D4	D5	Mean	D1	D2	D3	D4	D5	Mean
									2019 season									
S1	154.3	142.0	134.0	128.7	123.0	*136.4* ^{A}	17.67	18.67	19.33	19.00	19.00	*18.73* ^{A}	12.67	13.67	14.67	14.67	14.00	*13.93* ^{C}
S2	136.0	132.7	127.7	104.7	102.0	*120.6* ^{B}	16.00	17.33	21.33	17.67	17.33	*17.93* ^{A}	14.33	15.00	18.33	18.33	17.67	*16.73* ^{B}
S3	121.3	112.7	104.7	102.0	101.0	*108.3* ^{C}	16.33	16.33	20.00	19.67	17.33	*17.93* ^{A}	17.67	18.33	20.67	19.67	18.67	*19.00* ^{A}
Mean	137.2 ^{A}	129.1 ^{B}	122.1 ^{C}	111.8 ^{D}	108.7 ^{D}		16.67 ^{D}	17.44 ^{CD}	20.22 ^{A}	18.78 ^{B}	17.89 ^{C}		14.89 ^{D}	15.67 ^{C}	17.89 ^{A}	17.56 ^{A}	16.78 ^{B}	
									2020 season									
S1	144.7	145.3	134.0	127.0	122.0	*134.6* ^{A}	14.00	14.33	16.00	16.33	15.67	*15.27* ^{B}	8.00	10.33	12.67	12.00	11.33	*10.87* ^{C}
S2	140.0	127.7	116.7	117.0	115.7	*123.4* ^{B}	15.33	15.33	18.67	18.33	17.67	*17.07* ^{A}	13.00	14.33	16.00	15.67	15.00	*14.80* ^{B}
S3	136.0	128.7	122.3	104.7	98.00	*117.9* ^{B}	17.00	17.33	19.33	18.33	18.00	*18.00* ^{A}	14.67	16.33	19.00	17.00	16.67	*16.73* ^{A}
Mean	140.2 ^{A}	133.9 ^{B}	124.3 ^{C}	116.2 ^{D}	111.9 ^{E}		15.44 ^{C}	15.67 ^{C}	18.00 ^{A}	17.67 ^{A}	17.11 ^{B}		11.89 ^{E}	13.67 ^{D}	15.89 ^{A}	14.89 ^{B}	14.33 ^{C}	

S1: 31 May, S2: 15 June, S3: 30 June, D1: 285715 plants ha^{-1}, D2: 142860 plants ha^{-1}, D3: 95240 plants ha^{-1}, D4: 71430 plants ha^{-1}, D5: 57145 plants ha^{-1}. Italic means refer to sowing dates and none italic means refer to planting density. Means followed by different letters in the same direction differ significantly by LSD ($p \leq 0.05$).

ABLE 4. Number of seeds pod^{-1}, pods weight plant^{-1} (g) and 100-seed weight (g) of cowpea as affected by sowing date and planting densities and their interactions in both seasons

Sowing date	Number of seeds pod^{-1}						Pods weight plant^{-1} (g)						100-seed weight (g)					
	D1	D2	D3	D4	D5	Mean	D1	D2	D3	D4	D5	Mean	D1	D2	D3	D4	D5	Mean
									2019 season									
S1	15.00	16.67	18.00	16.00	15.67	*16.27* ^{B}	13.62	17.20	23.44	22.19	20.15	*19.32* ^{C}	6.13	6.04	6.82	6.75	6.21	*6.39* ^{C}
S2	14.33	19.00	19.33	19.00	15.00	*17.33* ^{AB}	19.32	25.15	31.42	29.11	24.02	*25.80* ^{B}	8.07	8.08	8.63	8.54	8.06	*8.28* ^{B}
S3	17.67	18.67	19.00	18.33	18.00	*18.33* ^{A}	17.18	24.39	34.83	34.57	30.45	*28.28* ^{A}	7.96	7.31	10.41	10.15	9.81	*9.13* ^{A}
Mean	15.67 ^{C}	18.11 ^{AB}	18.78 ^{A}	17.78 ^{B}	16.22 ^{C}		16.71 ^{E}	22.24 ^{D}	29.89 ^{A}	28.62 ^{B}	24.87 ^{C}		7.39 ^{C}	7.14 ^{C}	8.62 ^{A}	8.48 ^{A}	8.03 ^{B}	
									2020 season									
S1	13.00	13.67	14.33	13.33	13.33	*13.53* ^{B}	13.27	20.04	25.93	23.58	22.28	*21.02* ^{C}	6.39	6.34	7.36	6.97	6.87	*6.78* ^{C}
S2	12.67	17.00	18.00	16.00	14.00	*15.53* ^{A}	20.72	27.76	34.37	31.35	28.00	*28.44* ^{B}	7.83	7.33	8.87	7.93	7.82	*7.96* ^{B}
S3	12.00	16.67	17.00	16.33	16.00	*15.60* ^{A}	18.27	28.26	40.20	38.23	35.15	*32.02* ^{A}	7.13	6.53	10.68	10.59	8.88	*8.76* ^{A}
Mean	12.56 ^{D}	15.78 ^{AB}	16.44 ^{A}	15.22 ^{B}	14.44 ^{C}		17.42 ^{E}	25.35 ^{D}	33.50 ^{A}	31.05 ^{B}	28.47 ^{C}		7.12 ^{D}	6.73 ^{D}	8.97 ^{A}	8.50 ^{B}	7.86 ^{C}	

S1: 31 May, S2: 15 June, S3: 30 June, D1: 285715 plants ha^{-1}, D2: 142860 plants ha^{-1}, D3: 95240 plants ha^{-1}, D4: 71430 plants ha^{-1}, D5: 57145 plants ha^{-1}. Italic means refer to sowing dates and none italic means refer to planting density. Means followed by different letters in the same direction differ significantly by LSD ($p \leq 0.05$).

TABLE 5. Seed, hay and biological yield (kg ha^{-1}) of cowpea as affected by sowing date and planting densities and their interactions in both seasons

Sowing date	Seed yield (kg ha-1)						Hay yield (kg ha-1)						Biological yield (kg ha-1)					
	D1	D2	D3	D4	D5	Mean	D1	D2	D3	D4	D5	Mean	D1	D2	D3	D4	D5	Mean
2019 season																		
S1	783	930	1033	1102	1153	*1000* ^{C}	2073	2294	2481	2582	2464	*2379* ^{A}	2856	3224	3514	3684	3617	*3379* ^{A}
S2	1322	1334	1467	1144	1089	*1271* ^{B}	2691	2422	2430	2007	2138	*2338* ^{A}	4013	3756	3898	3151	3227	*3609* ^{A}
S3	1444	1468	1596	1382	1272	*1432* ^{A}	2581	2433	2363	2104	2147	*2325* ^{A}	4025	3901	3959	3486	3419	*3758* ^{A}
Mean	1183 ^{C}	1244 ^{B}	1366 ^{A}	1210 ^{BC}	1171 ^{C}		2448 ^{A}	2383 ^{AB}	2425 ^{A}	2231 ^{C}	2250 ^{BC}		3631 ^{A}	3627 ^{A}	3790 ^{A}	3440 ^{B}	3421 ^{B}	
2020 season																		
S1	489	647	1222	1220	973	*910* ^{C}	1196	1504	2743	2773	2111	*2065* ^{B}	1685	2151	3965	3993	3084	*2976* ^{B}
S2	1253	1367	1425	1451	1283	*1356* ^{B}	2672	2697	2854	2816	2547	*2717* ^{A}	3925	4064	4279	4267	3830	*4073* ^{A}
S3	1485	1538	1660	1437	1396	*1503* ^{A}	2841	2339	2596	2556	2643	*2595* ^{A}	4327	3877	4256	3993	4040	*4099* ^{A}
Mean	1076 ^{E}	1184 ^{D}	1436 ^{A}	1369 ^{B}	1217 ^{C}		2237 ^{C}	2180 ^{C}	2731 ^{A}	2715 ^{A}	2434 ^{B}		3312 ^{C}	3364 ^{C}	4167 ^{A}	4085 ^{A}	3651 ^{B}	

S1: 31 May, S2: 15 June, S3: 30 June, D1: 285715 plants ha^{-1}, D2: 142860 plants ha^{-1}, D3: 95240 plants ha^{-1}, D4: 71430 plants ha^{-1}, D5: 57145 plants ha^{-1}. Italic means refer to sowing dates and none italic means refer to planting density. Means followed by different letters in the same direction differ significantly by LSD ($P \leq 0.05$).

TABLE 6. Crop and harvest index (%) of cowpea as affected by sowing date and planting densities and their interactions in both seasons

Sowing date	Crop index (%)						Harvest index (%)					
	D1	D2	D3	D4	D5	Mean	D1	D2	D3	D4	D5	Mean
2019 season												
S1	38.36	40.92	42.42	42.94	47.21	*42.37* ^{C}	27.67	29.00	29.67	30.00	32.00	*29.67* ^{B}
S2	49.32	55.68	60.47	57.13	51.81	*54.88* ^{B}	33.00	35.67	37.67	36.33	34.00	*35.33* ^{A}
S3	56.48	60.44	67.67	65.79	59.95	*62.07* ^{A}	36.00	37.67	40.33	39.67	37.33	*38.20* ^{A}
Mean	48.05 ^{D}	52.35 ^{C}	56.85 ^{A}	55.28 ^{AB}	52.99 ^{BC}		32.22 ^{C}	34.11 ^{B}	35.89 ^{A}	35.33 ^{AB}	34.44 ^{B}	
2020 season												
S1	40.90	43.95	45.17	44.42	46.55	*44.20* ^{C}	29.00	30.33	31.00	30.67	31.67	*30.53* ^{C}
S2	47.14	50.79	50.05	51.52	50.98	*50.10* ^{B}	32.00	33.67	33.33	34.00	33.67	*33.33* ^{B}
S3	52.29	65.76	63.96	56.28	53.19	*58.30* ^{A}	34.33	39.67	39.00	36.00	34.67	*36.73* ^{A}
Mean	46.78 ^{D}	53.50 ^{A}	53.06 ^{AB}	50.74 ^{BC}	50.24 ^{C}		31.78 ^{B}	34.56 ^{A}	34.44 ^{A}	33.56 ^{A}	33.33 ^{A}	

S1: 31 May, S2: 15 June, S3: 30 June, D1: 285715 plants ha^{-1}, D2: 142860 plants ha^{-1}, D3: 95240 plants ha^{-1}, D4: 71430 plants ha^{-1}, D5: 57145 plants ha^{-1}. Italic means refer to sowing dates and none italic means refer to planting density. Means followed by different letters in the same direction differ significantly by LSD ($P \leq 0.05$).

The negative impacts of early sowing was more pronounced in seed yield could be attributed to luxuriant vegetative growth at the expense of the reproductive growth stage (pods attributes). Moreover, cowpea has strong adaptation that allows to set seed redeveloping and escaping heat stress. In this context, Mojaddam & Nouri (2014), Nwofia et al. (2018) and Hasanzadeh et al. (2019) documented that late sowing resulted in higher yield of cowpea over early sowing. Similarly, hay, biological yields ha^{-1} significantly differed in response to sowing date (Table 5). The maximum hay yield (2717 and 2595kg ha^{-1}) and biological yield (4073 and 4099kg ha^{-1}) were achieved by intermediate and late sowing compared to early sowing in the 2nd season, respectively. This might be due to cowpea plants is widely grown in the subtropics and tropics regions where it has strong adaptation and escaping heat stress during growing season. This is also corroborated by the findings of Nwofia et al. (2018) and Hasanzadeh et al. (2019). While, sowing date had no significant effect on hay and biological yield in 1st season. In addition, sowing date had significant effect on CI and HI in both growing seasons (Table 6). Late sowing exhibited the highest CI (62.07 and 58.30%) and HI (38.20 and 36.73%) followed by intermediate and early sowing date. The highest HI was registered under late sowing date which means higher seed formation against dry matter. HI measures the relative investment of plant resources in reproductive parts (Unkovich et al., 2010). Moreover, the increase of HI due to late sowing could be attributed to reduction in the vegetative growth against significant increase in seed yield. These results are in agreement with those reported by Taipodia & Nabam (2013) and Mojaddam & Nouri (2014) showing that late sowing in the resulted in higher yields and HI.

In respect of planting density, it had significant effect on final cowpea seed yield, hay and biological yields ha^{-1} (Table 5). The maximum seed yield (1366 and 1436kg ha^{-1}) was obtained by intermediate planting density during both seasons. Otherwise, the least seed yield was recorded by light planting density (1171kg ha^{-1}) in the first season and dense planting in the second season (1076kg ha^{-1}). These results almost followed the same patterns of yield components (Tables 3 and 4). Such increase in yield resulted from the intermediate density could be discussed based on decreased intra-competition between plants and struggling for the viable nutrients and enables cowpea plants to best use the available growth factors at different stages of growth and hence improving the yield components. The negative effect of the high planting density on seed yield could be attributes to the increase in plants population as a result of dense planting and consequently low penetration of light within cowpea canopy hence, high competition between plants, which accordingly reduces photosynthetic efficiency and source-sink relationship. On the contrary, significantly depressed in seed yield by light planting density is mainly due to the decreased in plants population per unit area. In addition, cowpea plants are one of non-dense planting crops which having not compensatory capacity, so, planting density is a very important agronomic practices that determine the productivity of cowpea. These results are in consonance with previous studies findings where significantly higher yield were found under the optimum planting density (Liu et al., 2008; Kamara et al., 2014; Giridhar et al., 2020). Noticeably, hay and biological yields significantly differed in response to planting density (Table 5). The higher hay and biological yields per ha were achieved by intermediate planting density during both seasons. The increase in hay and biological yields due to intermediate planting density could be attributed to reducing intraspecific competition among cowpea plants which accordingly improve the photosynthetic efficiency and hence dry matter accumulation. These findings are in consonance with previous studies findings where significantly higher yields were reported under the optimum planting density (Liu et al., 2008; Kamara et al., 2014; Giridhar et al., 2020). Similarly, CI and HI significantly differed in response to planting density (Table 6). The fewest CI (48.05 and 46.78%) and HI (32.22 and 31.78%) were obtained by dense planting density during both growing seasons, respectively. Otherwise, the higher CI and HI were recorded by intermediate planting density during both seasons. The increase of CI and HI could be attributed to the increase of seed yield under intermediate planting density. These results are in accordance with those reported by Liu *et al*. (2008), El Naim & Jabereldar (2010) and Bruns (2011) showing that HI was significantly depressed with increased planting density.

The two-way interaction displayed that the maximum seed yield (1596 and 1660kg ha^{-1}) was achieved by intermediate planting density under late sowing date during both seasons (Table 5).

While, seed yield of cowpea (783 and 489kg ha^{-1}) was significantly depressed when cowpea plants sown early with high planting density during the two growing seasons. Furthermore, the maximum hay yield (2691 and 2854kg ha^{-1}) was achieved by dense planting and intermediate density under intermediate sowing date in the 1st and the 2nd seasons, respectively. Moreover, the interaction results demonstrated that the uppermost biological yield (4025 and 4327kg ha^{-1}) was obtained by dense planting under late sowing date in both seasons. The superiority of hay or biological yield due to dense planting may be attribute to the increase in population per unit area. Late sowing date exhibited the higher CI and HI under intermediate planting density in both seasons. While, the fewest CI (38.36 and 40.90%) and HI (27.67 and 29.0%) were recorded by dense planting under early sowing date during both seasons. Such decrease in CI and HI could be attributed to an excessive vegetative growth due to dense planting where produced a significant increase in straw and total yields, hence, seed yield was significantly depressed. This supports the view of interactive impact between the optimum planting density and sowing date decreased the competition between cowpea plants and accordingly optimized plants growth which clearly manifested in improving biomass and seed yield.

Seed quality

The interaction between sowing dates and evaluated planting density was highly significant during both seasons (Fig. 1). The higher pure seed (96.35 and 91.65%) was produced by lighter planting density (D4 and D5) under late sowing date during the 1st season. In the 2nd season, it was recorded by lighter and intermediate planting density (94.86, 94.80 and 94.91%), respectively (Fig. 1A). While, the lowest pure seed (85.12 and 84.94%) was recorded by dense planting (D1 and D2) under intermediate sowing date during the 1st and the 2nd seasons, respectively. Otherwise, the uppermost shriveled seed (11.16 and 10.41%) was obtained by dense planting (D2) under intermediate sowing date during the 1st and the 2nd seasons, respectively (Fig. 1B). Whereas, the fewest shriveled seed (2.45%) was recorded by light planting (D4) under late sowing date during the 1st season. Besides, in the 2nd season, the fewest shriveled seed (4.06, 4.07 and 3.95%) was achieved by intermediate (D3) and the lighter planting densities (D4 and D5) under late sowing, respectively (Fig. 1B). Also, it is evident from Figure 1C that the highest infected seed (6.68 and 5.44%) was obtained by dense planting (D1) under early sowing date during the 1st and the 2nd seasons, respectively. Whereas the lowest infected seed was recorded by intermediate and the lighter planting densities under late sowing during both seasons (Fig. 1C).

This is attributed to a negative effect caused by dense planting regarding increase of mutual shading, excessive moisture level around plants as well as it forced plants for more elongation caused increase in plants lodging which led to pests infestation (fungi and insects) resulted in increase the damaged or infected seed especially under early sowing. In this connection, Early, Hampton (1999) reported that the optimum sowing date for producing high quality seed is not necessarily the same as that for seed production. Asante et al. (2001) reported that infestation by post flowering pests was significantly higher on cowpea planted in June than that of July and August. This might be due to when planted cowpea in June or early July, the flowering and pod formation stages escaped the peak population densities of the major post flowering pests. Moreover, Kanteh el al. (2014) showed that dense planting supported the highest population of insects compared to lower plant density. This gives an indication that insect population density is directly related to planting density, and this implies that the more plants are clustered together, the more the spread and establishment of insect pests on cowpea. Besides, Mansaray et al. (2020) showed that higher seed yield and better grain quality (fewer infected seed) were obtained when planting was done in September (late sowing) compared to June (early sowing). Otherwise, early planting of cowpea in mid- or late July resulted in the lowest pest densities compared with those planted at later dates (Abudulai et al., 2017).

Correlations of seed yield with other traits

The phenotypic correlation coefficient among all possible pairs of important traits is presented in Table 7. Plant height was significantly and negative correlated with pod length, number of pods $plant^{-1}$, number of seeds pod^{-1}, pod weight $plant^{-1}$ and 100-seed weight, biological yield, CI, HI and seed yield, however, had non- significant correlation with pure and infected seeds when the data were pooled over the years. Positive and highly significant correlations ($P< 0.01$) between pod length and number of pods $plant^{-1}$, number of seeds pod^{-1}, pod weight $plant^{-1}$ and 100-seed weight and infected seed.

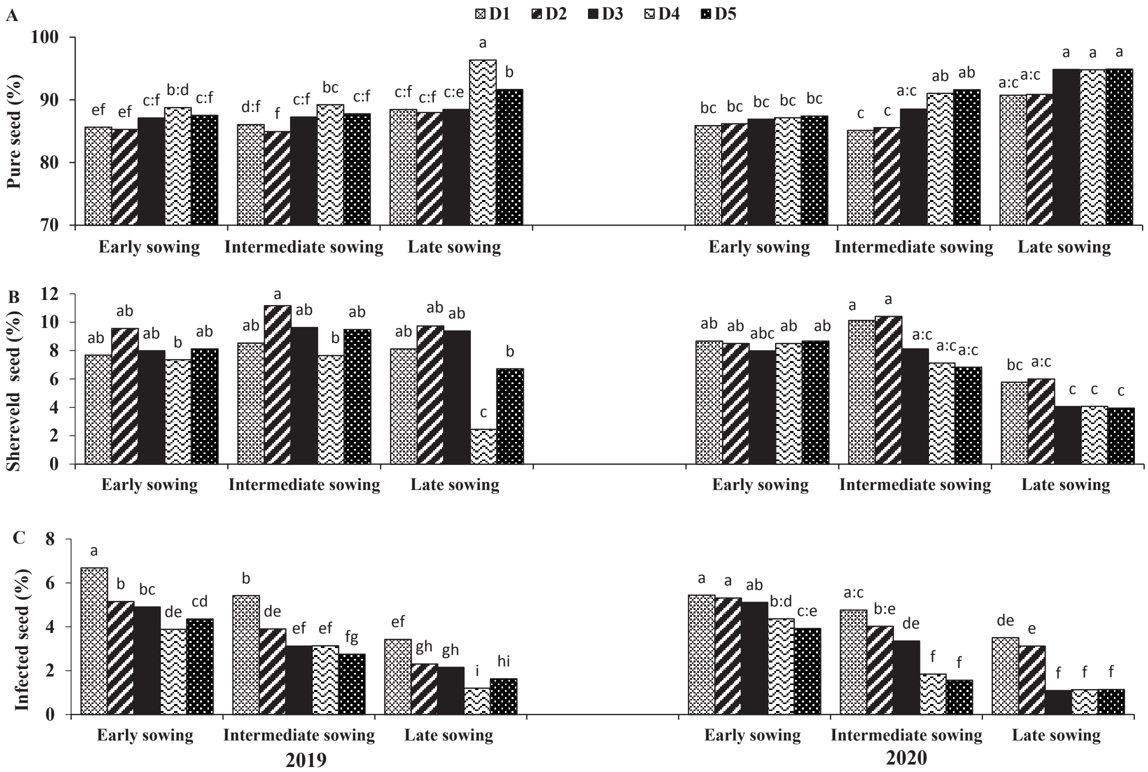

Fig. 1. Impact of sowing date on pure seed (%) (A), shriveled seed (%) (B) and infected seed (%) (C) under five planting density of cowpea [D1: 285715 plants ha^{-1}, D2: 142860 plants ha^{-1}, D3: 95240 plants ha^{-1}, D4: 71430 plants ha^{-1}, D5: 57145 plants ha^{-1}. The bars on the top of the columns represent the LSD (P≤ 0.05)]

Number of pods plant^{-1} had positive and significant correlations with number of seeds pod^{-1}, pod weight plant^{-1} and 100-seed weight, biological yield, CI, HI, pure seed and seed yield, but had negative and significant correlation with infected seed (-0.260**). Positive and highly significant correlations (P< 0.01) between number of seeds pod^{-1} and each of pod weight plant^{-1}, 100-seed weight, CI, HI and seed yield. Similarly, positive and highly significant correlations (P< 0.01) between pod weight plant^{-1} and each of 100-seed weight, biological yield, CI, HI and seed yield. 100-grain weight exhibited positive and highly significant correlations with biological yield, CI, HI and seed yield. Also, hay yield had positive and highly significant (P< 0.01) correlations with biological yield (0.943**) and seed yield (0.637**). Positive and significant correlations were registered between biological yield and CI, HI and seed yield, but had negative and highly significant correlation with infected seed (-0.366**). Furthermore, CI had positive and highly significant (P< 0.01) correlations with HI, pure seed and seed yield, while had negative and highly significant correlation with shriveled seed (-0.389**) and infected seed (-0.576**). Moreover, positive and highly significant correlations (P< 0.01) between HI and pure seed (0.544**) and seed yield (0.703**), but had negative and highly significant correlation with shriveled seed (-0.390**) and infected seed (-0.573**). Pure seed had negative and highly significant (P< 0.01) correlations with shriveled and infected seed, while had positive and highly significant correlation with seed yield (0.416**). Shriveled seed had negative and significant correlations with seed yield (-0.242**) while, it had a non-significant correlation with infected seed. Likewise, infected seed had negative and highly significant (P< 0.01) correlations with seed yield (-0.574**). Seed yield appeared to be positive and highly significant correlations (P< 0.01) with number of pods/plant (0.588**), number of seed/pod (0.332**), pod weight/plant (0.501**), 100-seed weight (0.557**), hay yield (0.637**), biological yield (0.858**), CI (0.695**), HI (0.703**), pure seed (0.416**). Otherwise, negative and significant correlations were registered between seed yield and plant height (-0.360**), shriveled seed (-0.242*) and infected seed (-0.574**). However, seed yield and pod length had a non-significant correlation (0.197). The results related to correlation studies (Table 7) revealed that seed yield had significant relationship with yield components, as well as, seed quality. These findings suggested that improvement of seed yield in cowpea is linked with the increase of these traits that might have good influence on seed yield. Likewise, Helmy et al. (2015), Srinivas et al. (2017), Walle et al. (2018) and Kalambe et al. (2019) reported a significant positive association between cowpea seed yield and yield components and seed quality.

Path coefficient

Direct and indirect effects of seed yield and yield contributing traits of cowpea across two seasons relative to correlation are presented in Table 8. In respect of direct effects, the results showed that number of pods plant^{-1} (0.385 "High"), pods weight plant^{-1} (0.025 "Negligible") and 100-seed weight (0.251 "Moderate") had positive direct effect on seed yield. For indirect effects, both number of pods plant^{-1}, pods weight plant^{-1} and 100-seed weight had positive effects on seed yield. Number pods plant^{-1} showed moderate positive indirect effect via pods weight plant^{-1} (0.263) and 100-seed weight (0.284). Pods weight plant^{-1} showed negligible positive indirect effect via number pods plant^{-1} (0.017) and 100-seed weight (0.021). 100-seed weight showed low positive indirect effect through number pods plant^{-1} (0.185) and moderate positive indirect effect via pods weight plant^{-1} (0.213). These results clearly indicate that number of pods plant^{-1}, pods weight plant^{-1} and 100-seed weight considered the major yield contributing traits that the cowpea breeder should take into account for production high yielding cowpea. Similar results were reported by several investigators (Singh et al., 2004; Naher et al., 2006; Srinivas et al., 2017). However, Walle et al. (2018) showed that 100-seed weight had exerted negative direct effect on seed yield.

Economic analysis

Economic performance of the interaction among sowing date and planting density was assessed (Table 9). The highest total income was achieved by late sowing date under intermediate planting density followed by late sowing date using dense planting. Likewise, the highest net income was achieved by late sowing date under intermediate planting density. On the other hand, the lowest net income was recorded by early sowing date using dense planting. The highest return invested was obtained by late sowing date under intermediate planting density. While, the lowest return invested was recorded by dense planting under early sowing date.

TABLE 7. Correlations (Pearson correlation coefficient) between the study traits in cowpea as calculated from the combined data across two years

Characters	Pod length	Number of pods plant^{-1}	Number of seeds pod^{-1}	Pods weight plant^{-1}	100-seed weight	Hay yield	Biological yield	Crop index	Harvest index	Pure seed	Shriveled seed	Infected seed	Seed yield
Plant height	-0.361**	-0.664**	-0.575**	-0.736**	-0.705**	-0.143	-0.251*	-0.297**	-0.292**	0.122	-0.156	0.041	-0.360**
Pod length		0.604**	0.612**	0.499**	0.434**	0.077	0.136	0.165	0.171	0.061	-0.192	0.302**	0.197
Number of pods plant^{-1}			0.780**	0.682**	0.738**	0.122	0.336**	0.626**	0.625**	0.266*	-0.199	-0.260*	0.588**
Number of seeds pod^{-1}				0.534**	0.544**	0.046	0.174	0.384**	0.376**	-0.017	-0.021	0.100	0.332**
Pods weight plant^{-1}					0.848**	0.180	0.336**	0.425**	0.427**	0.116	-0.115	-0.044	0.501**
100-seed weight						0.087	0.299**	0.614**	0.617**	0.183	-0.141	-0.167	0.557**
Hay yield							0.943**	-0.098	-0.087	0.009	0.061	-0.177	0.637**
Biological yield								0.235*	0.246*	0.186	-0.064	-0.366**	0.858**
Crop index									0.998**	0.544**	-0.389**	-0.576**	0.695**
Harvest index										0.544**	-0.390**	-0.573**	0.703**
Pure seed											-0.937**	-0.507**	0.416**
Shriveled seed												0.174	-0.242*
Infected seed													-0.574**

*, ** Significant at P= 0.05 and P= 0.01, respectively.

TABLE 8. Direct (Diagonal) and indirect effect of yield components on cowpea seed yield across two years relative to correlation

Characters	Number of pods plant^{-1}	Pods weight plant^{-1} (g)	100-seed weight (g)	Correlation with seed yield (kg ha^{-1})
Number of pods plant^{-1}	***0.385***	0.017	0.185	0.588
Pods weight plant^{-1} (g)	0.263	***0.025***	0.213	0.501
100-seed weight (g)	0.284	0.021	***0.251***	0.557

Bold and italic refers to direct effects of yield components on cowpea seed yield.

TABLE 9. Estimates of costs for inputs farm operation and economic return of cowpea as affected by sowing date (S) and planting density (D) averaged over the two growing seasons

Treat. (SXD)	Seed yield (kg ha^{-1})	Fodder yield (kg ha^{-1})	Seed yield income ($ ha^{-1})	Fodder yield income ($ ha^{-1})	Total income ($ ha^{-1})	Total cost ($ ha^{-1})	Net income ($ ha^{-1})*	Return invested ($)**
S1XD1	636	1635	878	204	1082	1387	-305	0.78
S1XD2	789	1899	1086	237	1323	1344	-21	0.98
S1XD3	1128	2612	1572	327	1899	1330	569	1.43
S1XD4	1161	2678	1631	335	1966	1323	643	1.49
S1XD5	1063	2288	1486	286	1772	1319	453	1.34
S2XD1	1288	2682	1770	335	2105	1387	718	1.52
S2XD2	1351	2560	1892	320	2212	1344	868	1.65
S2XD3	1446	2642	2025	330	2355	1330	1025	1.77
S2XD4	1298	2412	1855	302	2157	1323	834	1.63
S2XD5	1186	2343	1687	293	1980	1319	661	1.50
S3XD1	1465	2711	2088	339	2427	1387	1040	1.75
S3XD2	1503	2386	2135	298	2433	1344	1089	1.81
S3XD3	1628	2480	2359	310	2669	1330	1339	2.01
S3XD4	1410	2330	2119	291	2410	1323	1087	1.82
S3XD5	1334	2395	1962	299	2261	1319	942	1.71

* Net income ($ ha^{-1})= Total income - Total cost, ** Return invested ($)= Total income/ total cost

Conclusions

According to the current results, implementation of cowpea is a vital alternative approach to produce high quality seed yield plus acceptable seed yield especially in arid and semi-arid regions. Late sowing on 30 June caused significant increase in seed yield contributions, seed and biomass yield production, CI, HI and pure seed of cowpea. While early sowing on 31 May tended to produce the longest plant height and the uppermost infected seed. The intermediate planting density (95240 plants ha^{-1}) produced the higher seed yield components and yields ha^{-1}, CI and HI and pure seed. Results of interaction indicated that late sowing on 30 June attained the maximum seed yield for cowpea when intermediate planting density was used. Late sowing under lighter and intermediate planting densities exhibited the highest pure seed as well as the fewest shriveled and infected seed. Path coefficient analysis revealed that number of pods plant^{-1}, pods weight plant^{-1} and 100-seed weight had exerted positive and direct effect on seed yield of cowpea. We strongly recommend combining the late sowing strategy with intermediate planting density for optimal cowpea yield, seed quality as well as the highest net income under semi-arid conditions.

References

Abudulai, M., Kusi, F., Seini, S.S., Seidu, A., Nboyine, J.A., Larbib, A. (2017) Effects of planting date, cultivar and insecticide spray application for the management of insect pests of cowpea in northern Ghana. *Crop Protection*, **100**, 168-176.

Agbicodo, E.M., Fatokun, C.A., Muranaka, S., Visser, R.G.F., Linden van- der, C.G. (2009) Breeding drought tolerant cowpea: constraints, accomplishments, and future prospects. *Euphytica*, **167***,* 353-370.

Asante, S.K., Tamo, M., Jackal, L.E.N. (2001) Integrated management of cowpea insect pests using elite cultivars dates of planting and minimum insecticide application. *African Crop Science Journal,* **9**, 4706-4712.

Ayaz, S., Mc Niel, D.L., Mc Kenzie, B.A., Hill, G.D. (2001) Population and sowing depth effects on yield component of grain legumes. *10th Australian Agronomy Conference*, Hobart.

Bizeti, H.S., de Carvalho, C.G.P., de Souza, J.R.P., Destro, D. (2004) Path analysis under multicollinearity in soybean. *Agronomy Journal*, **47**, 669-676.

Black, G.R., Hartge, K.H. (1968) "*Methods of Soil Analysis*". Part 1. Physical and Mineralogical Methods. Klute, A. (Ed.), Soil Science Society of America, 2nd Edition, Madison, pp. 363-375.

Bruns, H. (2011) Comparisons of single-row and twin-row soybean production in the mid-south. *Agronomy Journal,* **103**, 1308–1313.

Chaudhary, R.R., Joshi, B.K. (2005) Correlation and path coefficient analyses in sugarcane. *Nepal Agriculture Research Journal*, **6**, 24-28.

Davis, D.W., Oelke, E.A., Oplinger, E.S., Doll, J.D., Hanson, C.V., Putnam, D. (1991) "*Field Crops Manure*", University of Mipesota, St Paul, MN5510. University of Wisconsin-Madison, W1 53706.

Dewey, D.R., Lu, K.H. (1959) A correlation and path coefficient analysis of components of crested wheat grass production. *Agronomy Journal*, **51**, 515-518.

Economic Reports (2020) "*Field Crops Statistical Year Book*". Ministry of Agriculture and Land Reclamation, Egypt. http://www.agr-egypt.gov.eg/

El Naim, A.M., Jabereldar, A.A. (2010) Effect of plant density and cultivar on growth and yield of cowpea (*Vigna unguiculata* L.Walp). *Australian Journal of Basic and Applied Sciences*, **4**(8), 3148-3153.

Elawad, H.O. (2000) The performance of selected cowpea (*Vigna unguiculata* L. Walp). Varieties in the sandy rainfed areas of Kordofan. Agricultural Research Corporation, Elobied, Sudan.

FAOSTAT (2021) Statistical Databases. Food and Agriculture Organization of the United Nations. http://www.fao.org/faostat/en/#data/QC.

Giridhar, K., Raju, P.S., Pushpalatha, G., Patra, C. (2020) Effects of plant density on yield parameters of cowpea (*Vigna unguiculata* L.). *International Journal of Chemical Studies,* **8**(4), 344-347.

Gomez, K.N., Gomez, A.A. (1984) "*Statistical Procedures for Agricultural Research*", John Wiley and Sons, New York, 2nd ed. p. 68.

Hafiz, N.A., Damarany, A.M. (2006) Variation in the susceptibility of some cowpea (*Vigna unguiculata* (L.) Walp) genotypes to infestation with certain pests in upper Egypt. *Assiut University Bulletin for Environmental Researches*, **9**(1), 8-15.

Hall, A.E. (2012) Phenotyping cowpeas for adaptation to drought. *Frontiers in Physiology,* **3**, 155.

Hampton, J.G. (1999) Producing quality seed: The problem of seed vigour. *Seed Symposium*, 53-61.

Hasanzadeh, M., Demir, I., Hazrati, N., Taşkın, M.B., Şahin, Ö. (2019) Seed performance of common bean and cowpea by priming and planting date. *Journal of Agricultural Sciences*, **64**(4), 381-397.

Hayat, F, Arif, M., Kakar, K.M. (2003) Effects of seed rates on mung bean varieties under dry land conditions. *International Journal of Agriculture and Biology,* **5**(1), 160-161.

Hector, V., Jody, S. (2002) Cowpea, sustainable agriculture green manure crops. SA-GM-6.

Helmy, A.A., Hassan, H.H.M., Ibrahim, H.I.M. (2015) Influence of planting density and bio-nitrogen fertilization on productivity of cowpea. *American-Eurasian Journal of Agricultural & Environmental Sciences,* **15**(10), 1953-1961.

ISTA, (2015) "*Handbook on Seed Health Testing*", ISTA, Zürich, Switzerland.

Kalambe, A.S., Wankhade, M.P., Deshmukh, J.D., Chavan, B.R., Shinde, A.V. (2019) Correlation studies in cowpea (*Vigna unguiculata* L.). *Journal* *of Pharmacognosy and Phytochemistry*, **8**(3), 321-323.

Kamara, A.Y., Sylvester, U.E., Tofa, A.I., Steve, B. (2014) Agronomic response of soybean to plant density in the Guinea savannas of Nigeria. *Agronomy Journal,* **106**, 1051–1059.

Kanteh, S.M., Norman, J.E., Sherman-Kamara, J. (2014) Effect of plant density and weeding regime on population and severity of aphids (*Aphis craccivora* Koch) and foliage beetles (*Ootheca mutabilis* Sahl) on cowpea in Sierra Leone. *International Journal of Agriculture and Forestry,* **4**(1), 24-33

Karungi, J., Adipala, E., Ogenga-Latigo, M.W., Kyamanywa, S., Oyobo, N. (2001) Pest management in cowpea. Part 1. Influence of planting time and plant density on cowpea field pests infestation in eastern Uganda. *Crop Protection*, **19**(4), 231-236.

Kumar, A., Sharma, K.D., Kumar, D. (2008) Traits for screening and selection of cowpea genotypes for drought tolerance at early stages of breeding. *Journal of Agriculture and Rural Development in the Tropics and Subtropics*, **109**(2), 191-199.

Liu, X.B., Jin, J., Wang, G.H., Herbert, S.J. (2008) Soybean yield physiology and development of high-yielding practices in Northeast China. *Field Crops Research,* **105**(3), 157-171.

Mafakheri, K., Bihamta, M.R., Abbasi, A.R. (2017) Assessment of genetic diversity in cowpea (*Vigna unguiculata* L.) germplasm using morphological and molecular characterization. *Cogent Food & Agriculture*, **3**(1), 1-9.

Mansaray, A., Mark, Y.K., Moseray, M.T., Kamara, A.Y., Conteh, A.R. (2020) Effect of cowpea cultivar, planting date and application of insecticide in the management of cowpea insect pests in South Eastern Sierra Leone. *Journal of Entomology and Nematology,* **12**(2), 39-45.

Mobbaser, H., Rezaei, A.M., Karimi, M., Eftekhari, A. (2006) Effect of row spacing and different sowing dates on phonological traits and grain yield of Cow Pea. *Proc.9th Iran Cong. Crop Sci.*, 27-29 Aug. Tehran University. Abooreihan Campus.

Mojaddam, M., Nouri, A. (2014) The effect of sowing date and plant density on yield and yield components of cowpea. *Bulletin of Environment, Pharmacology and Life Sciences*, **3**(8), 31-36.

MSTAT-C (1991) A microcomputer program for the design, management and analysis of agronomic research experiment. MSTAT Development Team, Michigan State University.

Naher, Z., Rabbani, M.G., Rahman, M.O., Garvey, E.J. (2006) Variability, correlation and path coefficient analysis of cowpea. *Journal of the Bangladesh Agricultural University*, **4**(1), 17-22.

Nderi, L.M. (2020) Effect of different spacing intervals on growth and yield of cowpea varieties in Kilifi County, Kenya. *M.Sc. Thesis*, Kenya Methodist University.

Nunes, H.G.G.C., Farias, V.D.S., Sousa, D.P., Costa, D.L.P., Pinto, J.V.N., Moura, V.B., et al. (2021) Parameterization of the Aqua Crop model for cowpea and assessing the impact of sowing dates normally used on yield. *Agricultural Water Management*, **252**. https://doi.org/10.1016/j.agwat.2021.106880

Nwofia, G.E., Onyekwere, C.R., Mbah, E.U. (2018) Genotype by planting date effects on cowpea in Humid Fringes, Southeast Nigeria. *Plant Breeding and Biotechnology*, **6**(2), 95-108.

Oyewale, R.O., Bamaiyi, L.J (2013) Management of cowpea insect pests. *Scholars Academic Journal of Biosciences*, **1**, 217-226.

Silva, A., Morais, O.M., Santos, J.L., d'Arede, L.O., Silva, C.J., Rocha, M.M. (2014) Estimativa de parâmetros genéticos em *Vigna unguiculata*. *Revista de Ciências Agrárias*, **37**(4), 399-407.

Singh, B., Bagade, A.B., Patel, D.U., Naik, M.R. (2004) Correlation and path analysis in cowpea. *Indian Journal of Pulses Research*, **17**(1), 84-85.

Srinivas, J., Kale, V.S., Nagre, P.K. (2017) Correlation and path analysis study in cowpea [*Vigna unguiculata* (L.) Walp.] genotypes. *International Journal of Current Microbiology and Applied Sciences*, **6**(6), 3305-3313.

Taipodia, R., Nabam, A.T. (2013) Impact of time of sowing, spacing and seed rate on potential seed production and fodder quality of cowpea [*Vigna unguiculata* (L.) Walp]. *Journal of Agriculture and*

Veterinary Science, **4**(4), 61-68.

Togay, Y., Togay, N., Dogan, Y. (2014) Effect of cowpea (*Vigna unguiculata* (L.) Walp.) sowing times applications on the yield and yield components. *Turkish Journal of Agricultural and Natural Sciences*, Special Issue, **1**(1147-1151).

Unkovich, M., Baldock, J., Forbes, M. (2010) Variability in harvest index of grain crops and potential significance for carbon accounting. *Advances in Agronomy,* **105**, 173–219.

Walle, T., Mekbib, F., Amsalu, B., Gedil, M. (2018) Correlation and path coefficient analyses of cowpea (*Vigna unguiculata* L.) Landraces in Ethiopia. *American Journal of Plant Sciences*, **9**, 2794-2812.

تحسين انتاجية لوبيا العلف من خلال ميعاد الزراعة والكثافة النباتية للتخفيف من حدة التغيرات المناخية

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الأقلمة للتغيرات المناخية من خلال ضبط ميعاد الزراعة واستخدام كثافة الزراعة المثلي يمكن أن تقلل من الأثار السلبية علي انتاجية لوبيا العلف. وفي هذا الصدد، فقد أجريت تجربة حقلية خلال الموسمين الزراعيين 2019 - 2020 في المزرعة التجريبية بمحطة البحوث الزراعية بكفر الحمام - محافظة الشرقية - مصر بهدف دراسة تأثير كل من ميعاد الزراعة (31 مايو - 15 يونيو - 30 يونيو) وكذلك تأثير الكثافة النباتية (285715 - 142860 - 95240 - 71430 - 57145 نبات/ هكتار) على محصول وجودة بذور لوبيا العلف. ويمكن تخليص النتائج المتحصل عليها علي النحو التالي:

1. أدت الزراعة المتأخرة في 30 يونيو إلى زيادة معنوية في كل من محصول البذور ومؤشرات المحصول، محصول الدريس، المحصول البيولوجي، دليل المحصول والحصاد، بالإضافة إلى زيادة نسبة البذور النقية (السليمة).
2. أدى زراعة لوبيا العلف بالكثافة النباتية المتوسطة (95240 نبات/ هكتار) إلى زيادة محصول البذور ومساهماته، محصول الدريس، المحصول البيولوجي والبذور السليمة.
3. لوحظ تداخل فعل معنوي بين ميعاد الزراعة والكثافة النباتية والصفات تحت الدراسة والتي تشير إلى إمكانية معظمة إنتاجية محصول بذور لوبيا العلف من خلال الزراعة أواخر يونيو واستخدام الكثافة النباتية المتوسطة (95240 نبات/ هكتار). كما تشير النتائج إلى انخفاض نسب البذور الضامرة والمصابة بالحشرات عند الزراعة بالكثافات المنخفضة (57145 - 71430 نبات/ هكتار) أو المتوسطة (95240 نبات/ هكتار) مع تأخير ميعاد الزراعة (30 يونيو).
4. أظهرت نتائج تحليل معامل المرور إلى أن عدد القرون/ النبات كان له تأثير مباشر إيجابي ومرتفع (0.385) على محصول البذور، بينما كان لدليل البذور تأثير مباشر إيجابي ومتوسط علي محصول البذور (0.251).