EFFECT OF ROW SPACING AND SEEDING RATES ON GROWTH, YIELD AND YIELD COMPONENTS OF CHICKPEA

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ABSTRACT

Chickpea response to five row spacing i.e. RS_1 (15cm), RS_2 (30 cm), RS_3 (45 cm), RS_4 (15/45 cm paired rows) and RS_5 (15/75 cm paired rows) and four seeding rates i.e. S_1 (60 kg ha^{-1}), S_2 (75 kg ha^{-1}), S_3 (90 kg ha^{-1}) and S_4 (100 kg ha^{-1}) were studied in split plot arrangements. Main plot consisted of row spacing (RS) whereas seed rates were kept in sub-plots. The experiment was laid out at Arid Zone Research Institute Bhakkar during 2004-05 and 2005-06 with the objective to determine proper row spacing and seed rate for standardization of plant population per unit area and their interactive effects on chickpea yield. Yield and yield components were significantly affected by row spacing and seeding rates. The interaction between row spacing and seeding rates were also significant for the characters studied. Maximum average number of pods $plant^{-1}$ (45.61), seeds pod^{-1} (1.957),100 seed weight (31.73 g) and CGR (9.66 g m^{-2} d^{-1}) was recorded in 45 cm row spacing x 75 kg seed rate ha^{-1} while minimum pods $plant^{-1}$ (28.94), seeds pod^{-1} (1.309) and CGR (6.40 g m^{-2} d^{-1}) were recorded in RS_1 x S_4 and minimum 100 seed weight (26.67 g) was recorded in 15/75 cm paired rows and 100 kg seed rate ha^{-1}. Maximum average biological yield (6975 kg ha^{-1}) and seed yield of 3110.32 kg ha^{-1} was recorded in 45 cm row spacing cum 75 kg seed rate ha^{-1} with harvest index of 44.63 % where as minimum biological yield (5296 kg ha^{-1}), seed yield (2002.26 kg ha^{-1}) and harvest index (36.10 %) was recorded in RS_1 x S_4. A row spacing of 45 cm with 75 kg seed rate ha^{-1} seems to be optimum for higher yield in chickpea under arid climatic conditions.

Key Words: ***Chickpea, Cicer arietinum, row spacing, planting geometry, seeding rates, harvest index.***

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INTRODUCTION

One of the main reasons of low yield of Chickpea (*Cicer arietinum* L.) is improper population. Too low and high plant population beyond a certain limit often adversely affects the crop yield. Number of plants per unit area influences plant size, yield components and ultimately the seed yield (Beech and Leach, 1989). Moreover, plant spacing in the field is also very important to facilitate aeration and light penetration in to plant canopy for optimizing rate of photosynthesis. There is very little information available on the relative contribution of various plant spacing towards yield and yield components and also their interaction. Both over and under plant densities resulted in significant yield decrease (Ashour, *et al.* 1995). Panwar *et al*. (1980) and Singh *et al*. (1994) reported row spacing of 45 cm increased chickpea yield compared to 30 and 50 cm spacing while Parihar (1996) indicated that row spacing had no significant effect on seed yield. Nawaz *et al*. (1995) and Felton *et al*. (1996) concluded that dry matter production and plant height were higher in higher plant populations (60 plant m^{-2}), and a population of 40 plants per square meter gave the maximum grain yield. Khan *et al.* (2001) concluded that narrow row spacing of 30 cm produced significantly maximum yield than that of wider row spacing of 70 cm. But Barary *et al.* (2002) observed the effect of row and plant spacing on seed yield was non-significant.

Seed rate of 40-50 and 75-100 kg ha^{-1} was found sufficient for small seeded and bold seeded varieties, respectively (Faroda and Singh, 1979) but Javadi *et al.* (2004) achieved more yield at 75 kg than that of 100 kg seed rate ha^{-1}. Yield increased with increase in plant population upto 50 plants m^{-2} for irrigated and population of 23 plants m^{-2} was ideal for rainfed chickpea (Saxena, 1979 and Lather, 2000). Contrary to this Karawasra and Faroda (1979) and McKenzie and Hill (1995) reported that seeding rate (30, 45 and 60 kg ha^{-1}) and row spacing (20, 30 and 40 cm) did not affect gram yield though higher plant population intercepted more solar radiation. Arshad *et al*. (2008) narrated that maximum seed yield was harvested at 75 kg seed rate ha^{-1}.

Among the yield components, number of pods $plant^{-1}$ and number of grains pod^{-1} and 1000 seed weight decreased with increasing seed rate (Aziz *et al*.1988 and Komatsu *et al*.1989). Tripathi and Singh (1989) and Abbas (1990) stated that number of branches $plant^{-1}$, pods $plant^{-1}$, seeds pod^{-1}, 1000 seeds weight, total dry matter and seed yield were affected significantly by different seed rates while Zahoor (1991) reported that 1000 seeds weight, biological yield, seed yield and harvest index were not significantly influenced by different seeding densities. Machado *et al.* (2006) narrated that row spacing did not affect yield but higher seeding rates increased yields in late seeded chickpea when moisture was not limiting.

Machado *et al.* (2003) revealed that biological and grain yield was increased when the seeding rate was increased from 17 to 33 seed m^{-2}, no further response was obtained by increasing seeding rates to 50 seeds m^{-2} and observed that row spacing did not influence grain yield but more yield was reported by Corp *et al*. (2004) at seeding rates of 44-55 seeds m^{-2} than lower seeding rates of 33-44 seeds m^{-2}. Regan *et al*. (2003) and Gan *et al*. (2003) recommended optimum plant population density for higher seed yield from 40 to 45 plants m^{-2} for Kabuli chickpea and from 45-50 plants m^{-2} for desi chickpea. Pu-hai Liu *et al.* (2003) concluded that as plant population increased from 20 to 50 plants m^{-2}, seed yield m^{-2} increased by 20% for desi and 27% for small seeded Kabuli chickpea. Lines *et al*. (2008) reported 70 % reduction in grain yield, when plant density was increased from 15 to 90 plants m^{-2}.

Keeping in view the contradictory findings about the spacing of crop, there is a dire need to find out appropriate row spacing and seed rate to harvest maximum yield of good quality chickpea. Therefore, the present study was designed to determine proper seed rate and row spacing for standardization of plant population per unit area and their interactive effects on yield and yield components of chickpea under agro-climatic conditions of Bhakkar, Punjab, Pakistan.

MATERIALS AND METHODS

A field experiment was conducted at Arid Zone Research Institute, Bhakkar Punjab, Pakistan during Rabi (winter) season of 2004-05 and 2005-06 on sandy loam soil with field capacity and permanent wilting point values of 14.67 and 5.40 % on volume basis, respectively. The research site is situated at latitude 31^{o}37N, longitude 71 ^{o} 02E.The experimental treatments consisted of five row spacing viz 15, 30, 45 cm (single rows), 15/45 and 15/75 cm paired rows and four seeding rates viz 60, 75, 90 and 100 kg ha^{-1}. The experiment was laid out in split plot design with row spacing in main plots and seeding rates in sub plots. The treatments were replicated four times. The subplot size was 2m x 9 m. The chickpea variety Bittle-98 was used as test material. The seed was sown with a single row hand drill. In each season normal cultural practices for raising successful chickpea crop were applied. The recommended dose of fertilizer i.e. 22 Kg N and 57 Kg $P_2 O_5$ ha^{-1} was applied in the form of urea and triple super phosphate at the time of seed bed preparation.

The crop was inter-cultured twice at 35 and 70 days after sowing. The weather data during the experimental period are presented in Table I. Data on number of pods $plant^{-1}$ were recorded on 10 randomly selected plants from each plot and average number of grains pod^{-1} were recorded from 20 randomly selected pods taken from ten randomly selected plants. Average weight of three samples was recorded for 100 grain randomly taken from grain yield of each treatment where as biological yield (kg ha^{-1}) and seed yield (kg ha^{-1}) was recorded on plot basis leaving the side rows as non-experimental. Dry matter accumulation was recorded from 5 randomly selected plants at twenty days interval and plants were dried in an electric oven at 70ºC till it dried to a constant weight and thereafter its dry matter yield was calculated on m^{-2} basis. Crop growth rate (CGR = (w_2-w_1/t_2-t_1) was calculated as proposed by Hunt (1978). Where $w_1 =$ dry weight of plants per unit area at time t_1, $w_2 =$ dry weight of plants per unit area at time t_2. Harvest index percentage (Economic yield/ Biological yield x 100) was also calculated. Data were subjected to analysis of variance (Steel and Torrie, 1997) to determine the significance of differences between treatments by using software package M.STATC. Least significance difference (LSD) test was applied for comparison of individual treatment means.

Table I ***Meteorological data recorded at Arid Zone Research Institute, Bhakkar, Punjab during 2004-05 and 2005-06***

Month	2004-05				2005-06			
	Temperature (°C)		Relative Humidity (%)	Rainfall (mm)	Temperature (°C)		Relative humidity (%)	Rainfall (mm)
	Max	Min			Max	Min		
Oct.	29.03	14.48	81.45	2.0	32.38	15.58	82.32	-
Nov.	24.06	9.46	80.10	-	25.8	8.5	78.19	-
Dec.	20.93	5.03	79.61	17.0	20.38	1.67	70.77	-
Jan.	16.32	2.70	74.71	37.0	18.29	2.58	74.94	4.0
Feb.	16.46	6.35	83.07	51.0	24.42	8.96	77.39	9.0
Mar.	24.50	12.19	80.70	25.0	25.67	11.22	79.35	15.0
Total	21.88*	8.37*	-	**132**	24.49*	8.09*	-	**28**

* Average

RESULTS AND DISUSSION

Pods Plant^{-1}

Number of pods plant^{-1}, an important primary yield component, was affected significantly by different row spacing and ranged from 31.46 to 40.47 during 2004-05 and 33.31 to 42.46 during 2005-06 . Maximum average pods plant^{-1} (41.47) were recorded in 45 cm single row followed by 15/45 cm paired rows with 36.80 pods plant^{-1} while the lowest number of pods (33.35) were recorded in 15/75 cm paired rows. Average number of pods plant^{-1} were increased 22.51 % as the row spacing was increased from 15 to 45 cm and when planting geometry was changed from 45 cm rows to 15/45 or 15/75 cm paired rows, the pods per plant decreased 11 and 20 %, respectively. When row spacing was shifted from 30 cm single rows to 15/45 cm paired rows, the number of pods plant^{-1} increased 3 % during 2004-05 and row geometry showed non-significant results during 2005-06. Higher number of pods plant^{-1} in 45 cm apart single rows might be due to proper adjustment of plants in the field which facilitated more aeration, greater light interception and more photosynthetic activity. While the lowest average number of pods (33.35) were recorded in 15/75 cm paired rows where plant to plant space was decreased. It was observed that plants stem remained thin in paired rows and it might be due to congested plant population within rows which caused lodging to some degree. These findings are in line with that of Ahmad *et al*. (2002) who reported maximum number of capsules plant^{-1} in wider row spacing in sesame.

Effect of seed rate on number of pods plant^{-1} was significant and average ranged from 31.33 to 39.97. Highest average number of pods per plant (39.97) were noted in 60 kg seed rate ha^{-1} closely followed by 75 kg seed rate ha^{-1} with 39.57 pods plant^{-1}, however, these were at same level of significance and the lowest number of pods per plant (31.33) were recoded in plots with 100 kg seed rate ha^{-1}. The lowest seed rate produced the highest number of pods per plant because of sufficient space and plants utilized more water, light, air and nutrients as a result, more photosynthetic activity, which eventually resulted in higher number of pods per plant. The lowest number of pods plant^{-1} were recoded in 100 kg seed rate ha^{-1}. The reduction in number of pods per plant (26 %) in higher seed rate might be due to higher number of plant per unit area where competition for nutrients, light, space and moisture was very tense as compared with the lower seed rate. Our findings can get support from that of Aziz *et al*. (1988) and Abbas (1990) who reported decreased number of pods plant^{-1} and 100 seed weight with increasing seed rate.

The interaction of row spacing and seed rates was significant for number of pods plant^{-1} and their average ranged from 28.94 to 45.61. The highest number of pods plant^{-1} (45.61) were recorded in 45 cm row spacing cum 75 kg seed rate ha^{-1}. The lowest number of pods plant^{-1} (28.94) were recorded in the treatment with 15 cm row spacing x 100 kg seed rate ha^{-1} (RS_1 x S_4) closely followed by treatment combination of RS_2 x S_4 and RS_5 x S_4 with 29.73 and 30.10 pods per plant and these treatments were non-significant statistically. Whenever the seed rate was increased to 100 kg ha^{-1} and planting geometry was shifted to 15 cm single rows or 15/45 and 15/75 cm paired rows, number of pods plant^{-1} decreased and were less from 45 cm single rows and 75 kg seed rate ha^{-1}. It might be due to greater number of plants per unit row length, which might have adversely affected the pod development, hence, pods formation were comparatively less than that of low seeding rate which resulted in greater competition for light, space and nutrients. Similar results were obtained by Nazir *et al*. (1991) who reported that all the yield contributing characters were favorably affected by planting geometry.

Seeds Pods^{-1}

Number of seeds per pod is considered an important factor that directly imparts an exploiting potential recovery in leguminous crops. Mean data regarding number of seeds per pod given in Table II. showed that it was significantly affected by row spacing. Maximum number of seeds per pod (1.884 and 1.869) were recorded in 45 cm row spacing followed by 15/45 cm row spacing (1.83 seeds pod^{-1}) while the minimum number of seeds per pod (1.684 and 1.494) were recorded in 15 cm row spacing during 2004-05 and 2005-06, respectively.

Seed rate also significantly affected the number of seeds per pod. Maximum number of seeds per pod were observed in 60 kg seed rate ha^{-1} (1.872 and 1.815 seeds per pod) followed by 75 kg seed rate ha^{-1} with 1.813 and 1.804 seeds pod^{-1} and minimum seeds per pod (1.720 and 1.549) were recorded in plots with 100 kg seed rate ha^{-1} during 1st and 2nd year investigation, respectively. On average, number of seeds pod^{-1} were decreased 11 % when seed rate was increased from 60 to100 kg ha^{-1}. The reasons for negative relationship between the seed rate and number of seeds pod^{-1} is that plants in the lowest seed rate had greater area per plant as compared to plants in higher seed rate thus plants in the plots of lower seed rate had more feeding area and more above ground space for photosynthesis. Eventually they absorbed more nutrients, intercepted more light and prepared more photosynthates, which ultimately resulted in more number of seeds pod^{-1}. These findings are in accordance with that of Aziz *et al*. (1988) and Komatsu *et al.* (1989) who reported decreased number of seeds pod^{-1} with increasing seed rate. The interaction of row spacing and seed rates was also significant for number of seeds per pod. The pods having maximum average number of seeds (1.957) were recorded in 45 cm row spacing cum 75 kg seed rate ha^{-1}(RS_3 x S_2) closely followed by RS_4 x S_2 and RS_3 x S_3 with 1.919 and 1.884 seeds pod^{-1} , however these treatments were at same level of significance. The lowest number of seeds pod^{-1} (1.309) were recorded in 15 cm row spacing with 100 kg seed rate ha^{-1}.

It was observed that where ever the seed rate was increased to 100 kg ha^{-1} with the row spacing of 15, 30, 15/45 or 15/75 cm, average (Two years) number of seeds pod^{-1} decreased 33, 18, 8 and 15 % respectively compared to RS_3 x S_2. The lowest number of seeds per pod might be due to relatively closer plants within row, which might have resulted in greater competition for light, space and nutrients.

Hundered Seed Weight (g)

Among various parameters contributing towards final yield of a crop, 100 seed weight is of prime importance. Data given in Table II. showed that means of row spacing significantly affected the 100 seed weight (g) and ranged from 26.10 to 28.10 g during 2004-05 and 30.30 to 31.63 g during 2005-06. Maximum average 100 seed weight (29.87 g) was recorded in 45 cm row spacing followed by 30 cm (29.04 g) and 15/45 cm paired rows with 100 seed weight of 28.75 g. While the lowest 100 seed weight (28.38 g) was recorded in 15/75 cm paired rows. On average, 100 seed weight was decreased 5 % when row spacing was shifted from 45 cm single rows to 15/75cm paired rows. Similarly, when rows were transformed from 30 cm to 15/45 cm paired rows, 100 seed weight was decreased 1%. It might be due to less light interception on account of congested rows and plant population. These findings can get support from that of Ahmad *et al*. (1997) who reported that the highest achenes weight at wider land area per plant. Similar findings were also reported by El-Sayed *et al*. (1984) and Gubbels and Dedio (1990).

Means of 100 seed weight were also significantly affected by seed rate and ranged from 27.68 to 30.15 g. The highest 100 seed weight (30.15 g) was observed in 75 kg seed rate ha^{-1} followed by 60 kg seed rate ha^{-1} with 100 seed weight of 29.40 g and the lowest 100-seed weight (27.68 g) was recorded in plots with 100 kg seed rate ha^{-1}. Hundred seed weight was increased 8 %, when seed rate was reduced from 100 to 75 kg ha^{-1}. It might be due to proper distribution of plants in the field area which harvested more light and nutrients from more available space plant^{-1}. Hundred seed weight decreased 7 % by increasing the seed rate from 60 to 100 kg ha^{-1}.These findings are in accordance with that of Aziz *et al.* (1988), Komatsu *et al.* (1989) and Lines *et al*. (2008) who reported decreased 100 seed weight with increasing seed rate. The interaction of row spacing x seed rates was significant at P=0.05 for 100 seed weight and average ranged from 26.67 to 31.73 g. The highest 100-seed weight (31.73 g) was recorded in plots with 45 cm row spacing cum seed rate of 75 kg ha^{-1} followed by RS_2 x S_2 with 29.92 g 100 seed weight. Lower number of plants per unit area at lower seed rate had more nutrients availability and greater partition to seed as compared to higher seed rate which resulted in more plump and bold seeds. Lowest density produced healthy individual seeds by receiving maximum sunlight for the process of photosynthesis. The lowest 100 seed weight (26.67 g) was recorded in the treatment with 15/75 cm paired rows cum 100 kg seed rate ha^{-1}. The lowest 100 seed weight in this treatment might be due to relatively closer plants within row which might have resulted in greater competition for light, space and nutrients and ultimately less assimilation of photosynthates.

Crop Growth Rate

Environmental factors play an important role in determining the crop growth rate (CGR). Data given in Table II. showed that means of crop growth rate were significantly affected by row spacing. High crop growth rate of 7.77 and 9.95 g m^{-2} d^{-1} was observed in 45 cm row spacing followed by 7.65 and 9.53 g m^{-2} d^{-1} in 15/45 cm paired rows during 2004-05 and 2005-06, respectively and were non-significant to each other. Minimum crop growth rate (7.20 g m^{-2} d^{-1}) was recorded in 15/75 cm paired rows (2004-05) and 7.79 g m^{-2} d^{-1} in 15 cm single rows (2005-06) in which intra row space was minimum and insufficient light interception reduced the crop growth rate. When rows arrangement was changed from 30 cm single rows to 15/45 cm paired rows, CGR was increased 3 and 3.36 % during 2004-05 and 2005-06, respectively and when rows were re-arranged from 45 cm single rows to 15/75 cm paired rows, CGR was decreased 7 and 17 % during 2004-05 and 2005-06, respectively. It might be concluded that 45 cm single rows may be suitable for higher CGR in chickpea. As the row spacing was decreased from 45 to 15cm row spacing, the CGR was also decreased 21 % due to decrease in space availability per plant.

Crop growth rate was also significantly affected by seed rates. The maximum crop growth rate was observed in 75 kg seed rate ha^{-1} with value of 8.22 and 9.85 g m^{-2} d^{-1} followed by 7.72 and 9.61 g m^{-2} d^{-1} in 90 kg seed rate ha^{-1} during 1st and 2nd year respectively. Minimum crop growth rate (6.63 g m^{-2} d^{-1}) was recorded in plots with 100 kg ha^{-1} seed rate during 1st year but during 2005-06, minimum CGR (7.51 g m^{-2} d^{-1}) was recorded in 60 kg seed rate ha^{-1}. Crop growth rate was decreased 11 and 24 % at under plant population and it was also decreased 19 and 11 % in case of over population. Crop growth was increased 13 % when seed rate was increased from 60 to 75 kg ha^{-1} but it was decreased from 6 to 19 % when seed rate increased from 75 to 90 and 100 kg ha^{-1}, respectively. It was depicted that crop growth rate was maximum at optimum plant population (75 kg seed rate ha^{-1}) and it was decreased in either case. The results coincide with that of ICRISAT (1991) where maximum CGR of 9.06 g m^{-2} d^{-1} was observed at reproductive stage. The interactions of row spacing and seed rates also showed significant differences for crop growth rate ranging from 6.19 to 8.32 g m^{-2} d^{-1} (2004-05) and 6.61 to 10.99 g m^{-2} d^{-1} (2005-06). Maximum average crop growth rate (9.66 g m^{-2} d^{-1}) was recorded in 45 cm row spacing x 75 kg seed rate ha^{-1} followed by 15/45 cm paired and 30 cm single rows with 75 kg seed rate ha^{-1} with CGR of 9.30 and 9.15 g m^{-2} $d^{-1,}$ respectively however, these treatments were at same level of significance. Minimum average crop growth rate (6.40 g m^{-2} d^{-1}) was recorded in the treatment with 15 cm row spacing and 100 kg seed rate ha^{-1}.

Dry Matter Accumulation (g m^{-2})

Increase in dry matter is one of the criterions of crop growth. The dry matter accumulation curves of different row spacing are given in Fig. 1-2. Dry matter accumulation was almost same in all the row spacing for a period of 90 DAS in both the years of experimentation. Differential behavior of different row spacing started from 110 DAS and maximum differences were observed in accumulated dry matter at 150 DAS and maximum dry matter accumulation was observed in 45 cm row spacing during both the years. It showed that biomass accumulation was slower in early growing period but dry matter accumulation in SR_3 (45 cm row spacing) in the latter part of growing period was higher and hence more crop growth rate and eventually the more seed yield. Different seeding rates also affected the dry matter accumulation and it was more or less same upto 110 DAS. During rapid growth period (110 -150 DAS -reproductive stage), 75 kg seed rate ha^{-1} accumulated the maximum dry matter of 893 and 895 g m^{-2} during 2004-05 and 2005-06, respectively and eventually the greater seed yield per unit area (Fig. 3-4).

Biological Yield (kg ha^{-1})

Biological yield is sum total of all dry matter produced through physiological and biochemical processes occurring in the plant system. Data given in Table III showed that means of row spacing significantly affected the biological yield during both years. Maximum biological yield (6884 and 6571 kg ha^{-1}) was recorded in 45 cm single rows followed by 15/45 cm paired rows with a biological yield value of 6766 and 6489 kg ha^{-1} during 2004-05 and 2005-06, respectively. While the lowest biological yield (5742 and 5782 kg ha^{-1}) was recorded in 15 cm row spacing. The lowest biological yield in 15 cm row spacing showed that row to row distance and per plant space is less. It might be due to lower photosynthetic efficiency in dense population. When row arrangement was shifted from 30 cm single rows to 15/45 cm paired rows, the average biological yield was increased 5.12 % and when row arrangement was changed from 45 cm single rows to 15/75 cm paired rows, the biological yield was decreased 10 %. Maximum biological yield recorded in 45 cm single rows advocates the suitability of row spacing in chickpea. These results are in line with those of Sohail *et al.* (2001) and Khan *et al*. (2001 [b]) who studied that a spacing of 50 cm between rows and 10 cm within row produced maximum biological yield as compared to 30 cm row spacing.

Biological yield was significantly affected by seed rates which ranged from 6343 to 6491 kg ha^{-1}. Maximum average biological yield of 6485 kg ha^{-1} was recorded in the plots with 75 kg seed rate ha^{-1} and the lowest biological yield of 6177 kg ha^{-1} was recorded in plots with 100 kg seed rate ha^{-1}. Higher biological yield was recorded in appropriate seed rate of 75 kg ha^{-1} than either more or less seed rates. In case of low plant populations, some of the yield components might have increased on individual plant basis but would have decreased on per unit area basis. On contrary, in thick populations number of plants increased per unit area and yield components decreased on individual basis and eventually the biological yield decreased. Similar results were quoted by Tripathi and Singh (1989) who reported that increasing seeding rates increased dry matter accumulation. The interaction of row spacing x seed rates was significant for biological yield. The maximum average biological yield (6975 kg ha^{-1}) was recorded in 45 cm single rows cum 75 kg seed rate ha^{-1}closely followed by biological yield value of 6958 and 6802 kg ha^{-1} in treatment combination of RS_4 x S_2 and RS_3 x S_1 however, these treatments were at same level of significance. While the lowest biological yield of 5296 kg ha^{-1} was recorded in the treatment with 15 cm row spacing and 100 kg seed rate ha^{-1}. Treatment combination of 45 cm single rows x 75 kg seed rate ha^{-1} gave maximum biological yield from either combination and said treatment combination (45 cm single rows x 75 kg seed rate ha^{-1}) might be better for good biological yield in chickpea.

Seed Yield (kg ha^{-1})

Seed yield is ultimate outcome of various physiological, biochemical and phenological processes occurring in the plant system. Data given in Table III showed that row spacing significantly affected the seed yield during both the years of investigation. Maximum average seed yield (2798.98 kg ha^{-1}) was recorded in 45 cm row spacing followed by 15/45 cm paired rows with average seed yield value of 2706.98 kg ha^{-1}. While the lowest yield (2379.19 kg ha^{-1}) was recorded in 15 cm single rows in which area per plant was lesser and average seed yield was also low in 15/75 cm paired rows. The seed yield was decreased 14, 10, 3 and 14 % when row spacing was decreased from 45 cm to 15 and 30 cm or increased from 45 cm to15/45 and 15/75 cm paired rows, respectively. Seed yield was increased 7 %, when row spacing was changed from 30 cm single rows to 15/45 cm paired rows and yield was reduced 16 % by modifying the row spacing from 45 cm to 15/75 cm paired rows. It might be inferred that 45 cm single rows might be optimum for obtaining higher yield in chickpea under given conditions. In paired rows, lodging also occurred to some extent due to which the seed yield was decreased. It might be concluded that 45 cm single row spacing is optimum for maximum light interception and aeration and eventually the seed yield which might be attributed to optimum space per plant that resulted in efficient light interception and photosynthetic activity. Panwar *et al*. (1980) and Singh *et al*. (1994) also reported increased seed yield with 45 cm row spacing.

Seed yield was significantly affected by seed rate during the course of study. Maximum seed yield (2703.70 and 2897.01 kg ha^{-1}) was recorded in 75 kg seed rate ha^{-1} followed by 60 kg seed rate ha^{-1} with average seed yield of 2570.88 kg ha^{-1} and lowest yield of 2372.43 kg ha^{-1} was recorded in the plots with 100 kg seed rate ha^{-1}. When seed rate was increased from 60 to 75 kg ha^{-1}, the yield was increased 8 %. Machado *et al.* (2006) narrated that higher seeding rates increased seed yield in chickpea when moisture was not limiting. Higher yields were recorded in appropriate seed rate of 75 kg ha^{-1} than either more or less seed rates. When seed rate was decreased 20 % (75 to 60 kg ha^{-1}), the yield was also decreased 5 % while increasing the seed rate from 75 to 90 or 100 kg ha^{-1}, decreased 9 and 15 % yield of chickpea, respectively (Lines *et al*. (2008). In case of low plant populations, some of the yield components might have increased on individual plant basis but would have decreased on per unit area basis. The lowest seed yield in 100 kg seed rate ha^{-1} may be due to relatively closer plants within row, which might have resulted in greater competition for light, space and nutrients. Accordingly, Javadi *et al*. (2004) concluded that drill pattern at 75 kg seed rate ha^{-1} yielded significantly than that of 100 kg seed rate ha^{-1}. On the basis of these results, it can be concluded that seed rate of 75 kg ha^{-1} and a row spacing of 45 cm is an appropriate seed rate and planting geometry for chickpea under arid climatic conditions. These findings are in line with that of Felton *et al.* (1996) who also reported that increasing sowing rates improved yield of chickpea. These results are also in concurrence with those of Machado *et al.* (2003) and Pu-hai Liu *et al.* (2003) and Arshad *et al*. (2008) reported maximum seed yield at 75 kg seed rate

ha^{-1}. The interaction of row spacing and seed rates was significant for seed yield. The maximum seed yield (3110.32 kg ha^{-1}) was recorded in 45 cm row spacing cum 75 kg seed rate ha^{-1} followed by RS_4 x S_2 and RS_3 x S_1 with yield value of 2962.07 and 2865.59 kg ha^{-1}, respectively. While the lowest seed yield of 2002.26 kg ha^{-1} was recorded in the treatment with 15 cm row spacing and 100 kg seed rate ha^{-1}.

The highest seed yield noted in seed rate of 75 kg ha^{-1} with 45 cm row spacing might be due to optimum number of plants per unit area which compensated the effect of decrease in other yield components like number of pods per plant, 100 seed weight, number of seeds per pod with either less or more seed rates. These components though decreased on *per se* basis, yet yield actually increased on per unit area basis. The plants grown with wider spacing had more area of land around them to draw the nutrition and had more solar radiation to absorb for better photosynthetic process and hence performed better at individual basis. The reason for deviation of this linearity in case of seed yield per unit area is that the yield does not entirely depend upon the performance of individual plant but also interact with the total number of plants per unit area and yield contributing parameters.

Harvest Index

Harvest index is a measure of physiological productivity potential of a crop variety under favorable environmental conditions. It is the ability of a crop plant to convert the dry matter into economic yield. Data given in Table III. showed that harvest index was significantly affected by row spacing and average ranged from 39.58 to 41.66 %. The highest harvest index percentage (41.66) was recorded in 45 cm row spacing followed by 41.18 % in 15 cm single rows, however these were at same level of significance while the lowest harvest index (39.58 %) was recorded in 30 cm row spacing. Minimum H.I was recorded where within row space was less and main portion of photosynthates were utilized in harvesting sunlight instead of yield and yield components. When row spacing was changed from 30 cm single rows to 15/45 cm paired rows, the harvest index was increased 2.38 % but when row spacing was shifted from 45 cm single rows to 15/75 cm paired rows, harvest index was decreased 4.99 %. Maximum harvest index in 45 cm row spacing might be attributed to greater space between the rows that resulted in efficient light interception and photosynthetic activity. The least value of harvest index might be due to relatively closer plants within row which might have resulted in greater competition for light, space and nutrients and invested photosynthates for attaining superiority instead of yield and yield components. These results are in accordance with that of Nazir *et al.* (1991) who reported that all the yield contributing characters were favorably affected by growing the lentil crop in 15/45 cm apart double row strips and recorded highest yield (14.49 quintals ha^{-1}) and harvest index (44.00 %) against harvest index (41.64 %) in 30 cm apart single rows and lowest yield (12.79 quintals ha^{-1}) in case of four row strip planting system (15/75cm). Means of harvest index were also significantly affected by seed rates.

Maximum harvest index of 41.38 and 44.71 % was observed in 75 kg seed rate ha^{-1} followed by 40.49 and 42.24 % harvest index in 60 kg seed rate ha^{-1} and the least harvest index (36.79 and 39.40 %) was recorded in plots with 100 kg seed rate ha^{-1}during 2004-05 and 2005-06, respectively. Optimum seed rate of 75 kg ha^{-1} had produced significantly highest harvest index while higher seed rate of 100 kg ha^{-1} had produced minimum harvest index. This might be due to the fact that in case of low seed rate, seed yield to biological yield ratio was higher as compared to higher seed rate where seed yield to biological yield ratio was low. As harvest index value is positively correlated with seed yield and had negative correlation with biological yield therefore the harvest index value was higher in low seed rate and minimum in higher seed rate. Significant differences in harvest index value have also been reported by Jan *et al.* (2000) who reported progressive decrease in harvest index with increasing seed rates. There was an inverse relationship between the seed rate and harvest index because of more nutrient availability and more partition of photosynthetic products to seed at lower seed rate as compared to higher seed rate. The harvest index is not highly heritable but varies inconsistently with season, management and environment. However, it was concluded that lower seed rates of chickpea are the optimum for higher harvest index. The interactions of row spacing cum seed rates were also significant for harvest index. Maximum harvest index (44.63 %) was recorded in plots with 45 cm row spacing and 75 kg seed rate ha^{-1}closely followed by 15 cm row spacing x 75 kg seed rate ha^{-1}(44.54 %) however these were at same level of significance. The lowest value of harvest index (34.17 and 38.03 %) was recorded in 15 cm row spacing x 100 kg seed rate ha^{-1}. The least value of harvest index % might be due to relatively closer plants within row which might have resulted in greater competition for light, space and nutrients which have increased the plant height and decreased the harvest index values.

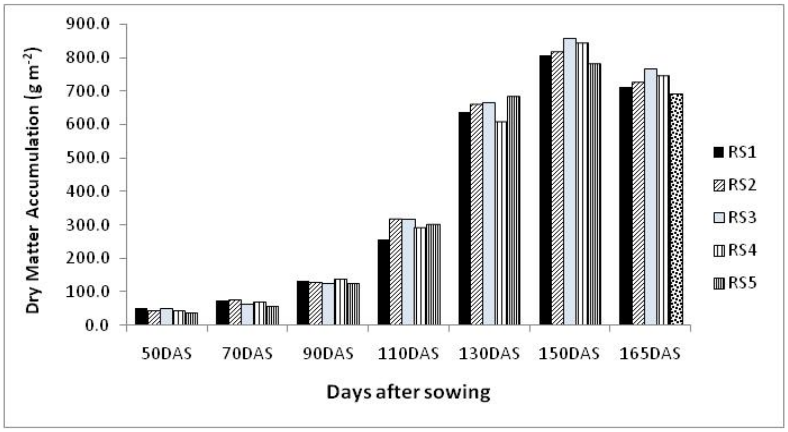

Fig.1 Effect of row spacing on dry matter accumulation during 2004-05

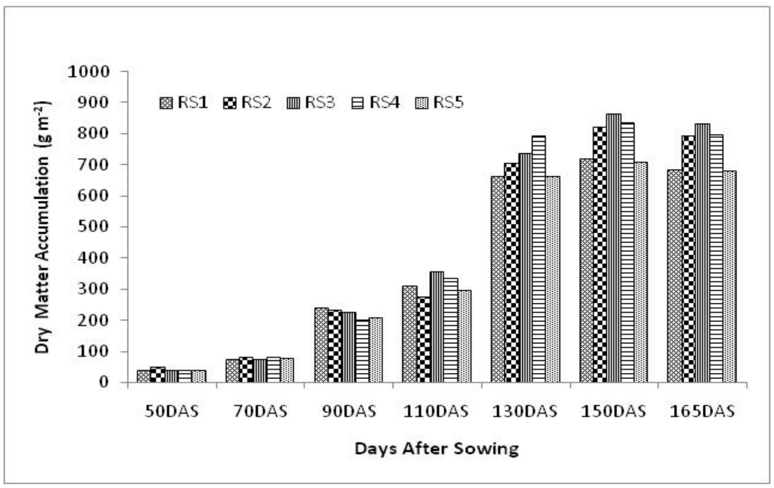

Fig.2 Effect of row spacing on dry matter accumulation during 2005-06

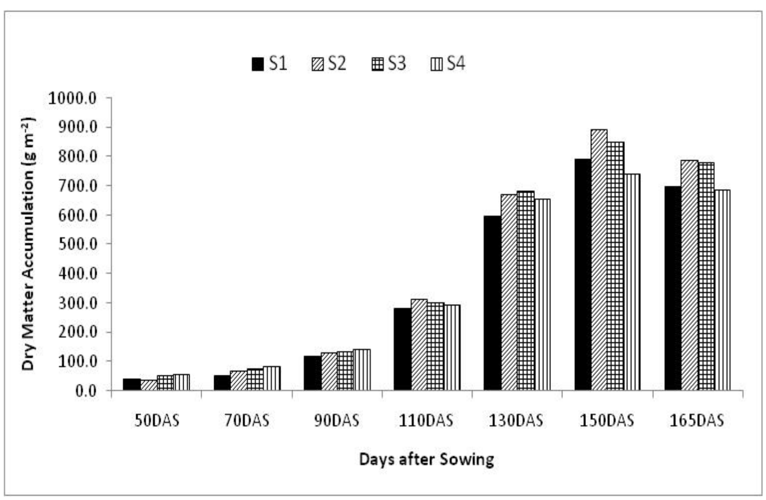

Fig.3 Effect of seed rate on dry matter accumulation during 2004-05

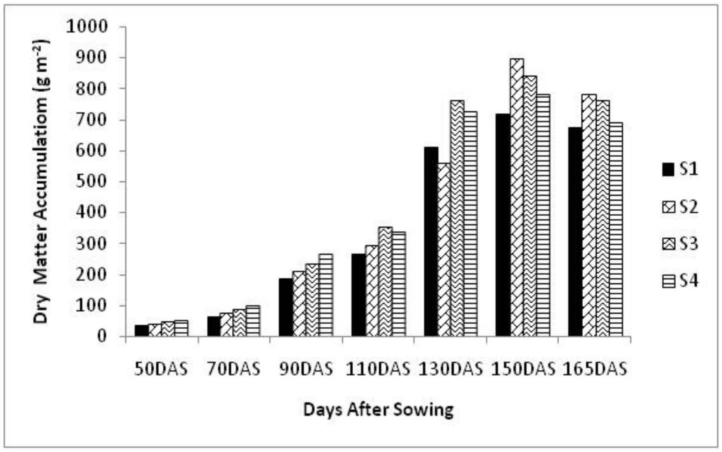

Fig.4 Effect of seed rate on dry matter accumulation during 2005-06

Table II ***Effect of row spacing and seed rate on number of pods plant^{-1}, seeds pod^{-1}, 100 seed weight (g) in chickpea and crop growth rate (g m^{-2} d^{-1})***

Treatments	Pods plant^{-1}			Seeds pod^{-1}			100 seed weight			Crop growth rate		
	04-05	05-06	Ave	04-05	05-06	Ave	04-05	05-06	Ave	04-05	05-06	Ave
A- Row spacing (RS)												
RS_1 (15cm)	31.46	36.23	33.85	1.684	1.494	1.589	26.99	30.45	28.72	7.25	7.79	7.52
RS_2 (30cm)	35.37	37.68	36.53	1.743	1.689	1.716	27.10	30.98	29.04	7.44	9.22	8.33
RS_3 (45cm)	40.47	42.46	41.47	1.884	1.869	1.877	28.10	31.63	29.87	7.77	9.95	8.86
RS_4(15/45cm)	36.41	37.19	36.80	1.833	1.834	1.834	26.10	31.40	28.75	7.65	9.53	8.59
RS_5(15/75cm)	33.39	33.31	33.35	1.794	1.700	1.747	26.45	30.30	28.38	7.20	8.23	7.72
$LSD_{0.05}$	0.91	0.63		0.048	0.064		0.26	0.51		0.20	0.38	
B-Seed rate (kg ha^{-1})												
S_1 (60kg ha^{-1})	39.53	40.40	39.97	1.872	1.815	1.844	27.55	31.25	29.40	7.28	7.51	7.40
S_2 (75kg ha^{-1})	38.82	40.31	39.57	1.813	1.804	1.809	27.82	32.48	30.15	8.22	9.85	9.04
S_3 (90kg ha^{-1})	33.93	37.34	35.63	1.748	1.700	1.724	26.38	30.90	28.64	7.72	9.61	8.67
S_4 (100kg ha^{-1})	29.40	33.26	31.33	1.720	1.549	1.635	26.04	29.31	27.68	6.63	8.81	7.72
$LSD_{0.05}$	0.85	0.52		0.035	0.053		0.22	0.43		0.15	0.32	
C-Row spacing x Seed rate												
$RS_{1\,x}\,S_1$	38.87	41.45	40.16	1.737	1.735	1.736	28.45	29.21	28.83	6.95	7.06	7.01
$RS_{1\,x}\,S_2$	32.56	37.08	34.82	1.825	1.572	1.699	26.74	32.73	29.74	8.13	8.82	8.48
$RS_{1\,x}\,S_3$	28.82	33.13	30.98	1.612	1.612	1.612	26.51	30.49	28.50	7.74	8.69	8.22
$RS_{1\,x}\,S_4$	25.59	32.28	28.94	1.563	1.055	1.309	26.26	29.38	27.82	6.19	6.61	6.40
$RS_{2\,x}\,S_1$	39.26	39.70	39.48	1.788	1.775	1.782	27.33	31.77	29.55	7.16	10.12	8.64
$RS_{2\,x}\,S_2$	39.67	41.63	40.65	1.862	1.850	1.856	28.05	31.79	29.92	8.19	10.11	9.15
$RS_{2\,x}\,S_3$	34.23	38.28	36.26	1.622	1.625	1.624	26.49	30.84	28.67	7.65	10.04	8.85
$RS_{2\,x}\,S_4$	28.32	31.13	29.73	1.700	1.505	1.603	26.52	29.50	28.01	6.77	9.08	7.93
$RS_{3\,x}\,S_1$	43.91	44.10	44.01	1.875	1.850	1.863	28.22	31.52	29.87	7.70	7.93	7.82
$RS_{3\,x}\,S_2$	44.26	46.95	45.61	1.950	1.963	1.957	29.67	33.78	31.73	8.32	10.99	9.66
$RS_{3\,x}\,S_3$	38.38	39.88	39.13	1.888	1.880	1.884	27.64	31.54	29.59	7.95	10.24	9.10
$RS_{3\,x}\,S_4$	35.35	38.93	37.14	1.825	1.775	1.800	26.85	29.69	28.27	7.10	10.64	8.87
$RS_{4\,x}\,S_1$	39.90	39.48	39.69	1.850	1.888	1.869	26.38	31.43	28.91	7.64	7.66	7.65
$RS_{4\,x}\,S_2$	42.47	41.55	42.01	1.900	1.938	1.919	26.85	32.33	29.59	8.29	10.28	9.30
$RS_{4\,x}\,S_3$	33.91	35.55	34.73	1.783	1.713	1.748	25.58	31.22	28.40	7.89	10.14	9.02
$RS_{4\,x}\,S_4$	29.36	32.18	30.77	1.800	1.800	1.800	25.60	29.61	27.61	6.80	10.04	8.42
$RS_{5\,x}\,S_1$	35.73	36.28	36.01	1.813	1.825	1.819	27.35	32.34	29.85	6.92	7.24	7.08
$RS_{5\,x}\,S_2$	35.14	35.33	35.24	1.825	1.700	1.763	27.78	31.79	29.79	8.17	9.05	8.61
$RS_{5\,x}\,S_3$	34.31	33.85	34.08	1.825	1.663	1.744	25.66	30.40	28.03	7.35	8.93	8.14
$RS_{5\,x}\,S_4$	28.40	31.80	30.10	1.712	1.612	1.662	24.99	28.35	26.67	6.30	7.68	6.99
$LSD_{0.05}$	1.91	1.16		0.078	0.119		0.49	0.97		0.33	0.73	

Table III *Effect of seed rate and row spacing on biological yield (kg ha^{-1}), seed yield (kg ha^{-1}) and harvest index % in chickpea*

Treatments	Biological yield (kg ha^{-1})			Seed yield (kg ha^{-1})			Harvest index (HI)		
	2004-05	2005-06	Ave	2004-05	2005-06	Ave	2004-05	2005-06	Ave
A- Row spacing (RS)									
RS_1 (15cm)	5742	5782	5762	2316.25	2442.13	2379.19	40.12	42.24	41.18
RS_2 (30cm)	6416	6193	6304	2443.11	2584.12	2513.62	38.02	41.73	39.88
RS_3 (45cm)	6884	6571	6727	2776.96	2820.99	2798.98	40.38	42.93	41.66
RS_4(15/45cm)	6766	6489	6627	2686.98	2726.98	2706.98	39.62	42.03	40.83
RS_5(15/75cm)	6174	5955	6064	2379.75	2426.99	2403.37	38.39	40.76	39.58
$LSD_{0.05}$	101.00	60.06		30.28	21.21		0.27	0.77	
B-Seed rate (kg ha^{-1})									
S_1 (60kg ha^{-1})	6364	6075	6219	2575.75	2566.00	2570.88	40.49	42.24	41.37
S_2 (75kg ha^{-1})	6491	6479	6485	2703.70	2897.01	2800.36	41.38	44.71	43.05
S_3 (90kg ha^{-1})	6389	6229	6309	2477.55	2566.01	2521.78	38.08	41.19	39.64
S_4 (100kg ha^{-1})	6343	6012	6177	2375.95	2368.91	2372.43	36.79	39.40	38.10
$LSD_{0.05}$	99.0	53.37		26.79	17.08		0.65	0.58	
C-Row spacing x Seed rate									
$RS_{1\ x}\ S_1$	6069	5700	5884	2475.75	2453.24	2464.49	40.79	40.04	40.42
$RS_{1\ x}\ S_2$	5722	6075	5898	2447.57	2776.34	2611.95	43.37	45.70	44.54
$RS_{1\ x}\ S_3$	5606	6026	5816	2362.04	2517.16	2439.60	42.17	41.77	41.97
$RS_{1\ x}\ S_4$	5569	5024	5296	1979.62	2024.91	2002.26	34.17	38.03	36.10
$RS_{2\ x}\ S_1$	5978	5936	5957	2327.42	2460.23	2393.82	39.94	41.45	40.70
$RS_{2\ x}\ S_2$	6239	6334	6286	2549.85	2819.09	2684.47	41.01	44.55	42.78
$RS_{2\ x}\ S_3$	6769	6211	6490	2451.37	2626.00	2538.68	35.94	42.28	39.11
$RS_{2\ x}\ S_4$	6681	5993	6337	2443.82	2432.09	2437.95	36.19	38.65	37.42
$RS_{3\ x}\ S_1$	7033	6571	6802	2881.17	2850.01	2865.59	40.96	43.37	42.17
$RS_{3\ x}\ S_2$	7083	6867	6975	3071.66	3148.99	3110.32	43.39	45.86	44.63
$RS_{3\ x}\ S_3$	6819	6509	6664	2544.33	2680.04	2612.18	37.33	41.17	39.25
$RS_{3\ x}\ S_4$	6601	6337	6469	2610.70	2600.12	2605.41	39.38	41.03	40.21
$RS_{4\ x}\ S_1$	6903	6328	6615	2742.07	2656.12	2699.09	39.73	41.97	40.85
$RS_{4\ x}\ S_2$	6931	6985	6958	2867.83	3056.32	2962.07	41.38	43.76	42.57
$RS_{4\ x}\ S_3$	6775	6370	6572	2542.33	2670.09	2606.21	37.53	41.92	39.73
$RS_{4\ x}\ S_4$	6458	6274	6366	2595.69	2523.78	2559.73	39.87	40.23	40.05
$RS_{5\ x}\ S_1$	5836	5839	5837	2552.39	2412.20	2482.29	42.02	41.31	41.67
$RS_{5\ x}\ S_2$	6478	6132	6305	2579.11	2687.02	2633.06	39.81	43.32	41.57
$RS_{5\ x}\ S_3$	5978	6018	5998	2237.65	2339.02	2288.33	37.44	38.87	38.16
$RS_{5\ x}\ S_4$	6405	5831	6118	2449.91	2265.00	2357.45	34.32	38.84	36.58
$LSD_{0.05}$	221.40	120.20		59.47	38.07		1.46	1.29	

CONCLUSION AND RECOMMENDATIONS

Through over viewing all discussions, it is accomplished that 45 cm row spacing with 75 kg seed rate ha^{-1} in chickpea crop affected positively different agronomic parameters like number of pods plant^{-1} , number of seeds pod^{-1} and 100 seed weight which ultimately contributed to increased biological yield, grain yield and harvest index and concluded that a 45 cm single row spacing with 75 kg seed rate ha^{-1} is the optimum planting geometry for efficient light interception and photosynthetic activity and same is proposed to the farmers for better yield in chickpea under given environmental conditions.

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