Agric Res J **60** (2) : 190-195, *April* 2023
DOI No. 10.5958/2395-146X.2023.00030.3

GROWTH PARAMETERS AND COMPETITIVE INDICES OF BED PLANTED CHICKPEA (*Cicer arietinum* L.) AS INFLUENCED BY DIFFERENT INTERCROPPING SYSTEMS

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ABSTRACT

An experiment was carried out in a randomised block design to find out the effect of chickpea based intercropping systems on growth parameters and competitive indices, with four replications at Punjab Agricultural University, Ludhiana, during *rabi* seasons of 2017-18 and 2018-19. Results showed that intercropping systems did not significantly influence the plant height of chickpea but DMA, LAI, chlorophyll index and PAR interception in chickpea was significantly reduced with different intercropping systems. Among various intercropping systems, chickpea + oats fodder (2:1) was found to be best intercropping system as it produced higher land equivalent ratio, area time equivalent ratio and monetary advantage index in comparison to sole chickpea. Growing of oats fodder with chickpea showed more compatibility and there was no competition and adverse effect of oats fodder on chickpea. Chickpea + oats fodder (4:1), chickpea + linseed (2:1) and chickpea + linseed (4:1) also performed better with respect to Land equivalent ratio (LER), Area time equivalent ratio (ATER) and Monetary advantage Index (MAI). Oilseed rape and barley showed negative impact on growth parameters and were aggressive when they grow as intercrops with chickpea association.

Keywords: Bed planted chickpea, Competitive indices, Growth parameters, Intercropping systems

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India is a major pulse growing country. Pulses are the major source of protein supplement food and supply some essential amino acids. Chickpea (*Cicer arietinum* L.) is the third most important pulse crop produced after dry bean and peas in the world. During famine period, this pulse crop gains more importance because of its high nutritional value (Prasad, 2012). In India, it is cultivated on an area of 28.8 m ha with production of 25.5 m t and productivity of 885 kg/ha (Anonymous, 2021). In Punjab, it was grown as *rabi* crop with an area of 2.0 thousand hectares, production of 2.6 thousand tonnes and the productivity of 1322 kg/ha (Anonymous, 2022).

There is a need to increase area or productivity of pulses to bridge the gap between demand and supply of pulse production and to ensure food security for burgeoning population. To ensure better productivity and profitability per unit area per unit time, crop diversification is required (Shubha *et al.,* 2015). More attention is required in the pulse production to meet the demands of burgeoning population and the production can be increased through the intercropping systems (Priya *et al.,* 2022)**.** The main objective of the intercropping is increasing production per unit land area per unit time and better utilization of resources. Moreover, intercropping of legume with other crops is beneficial as it reduces the input costs and saves the farmer from complete crop failure. In India, chickpea is generally intercropped with wheat, lentil, pea, safflower and coriander. There is possibility of growing intercrops like oats fodder, barley, linseed and mustard in furrows of bed planted chickpea. The bed planting technique is a new concept under chickpea cultivation. It protects the plant from heavy rainfall or excess irrigation and also helps in lowering the competition between intercrop and chickpea. No systematic research and adequate technologies have been reported in Punjab on intercropping of different crops in chickpea and keeping view the above facts, the present study was carried out to assess effect the different intercropping systems on growth and various competitive indices in chickpea.

MATERIALS AND METHODS

A field experiment was carried out during two consecutive *rabi* seasons of 2017-18 and 2018-19 at the Students' Research Farm of Department of Agronomy, Punjab Agricultural University, Ludhiana. It is located at 30° 54′ N latitude, 75° 48′ E longitude in Trans-Gangetic agro-climatic zone and an elevation of 247 meters height above the mean sea level. The soil texture of the experiment field was loamy sand, having pH (7.0 and 7.1), EC (0.18 and 0.17 dS m^{-1}),

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Date of receipt: 30. 01. 2023, Date of acceptance: 30.04.2023

OC (0.21 and 0.20 %), available N (169.3 and 188.1 kg/ha), available P (24.9 and 22.5 kg/ha) and available K (157.3 and 154.5 kg/ha), respectively during both years of study. The experiment was laid out in randomised block design in four replications with thirteen treatment combinations:T_1: Chickpea + oats fodder (2:1), T_2: Chickpea + oats fodder (4:1), T_3: Chickpea + linseed (2:1), T_4: Chickpea + linseed (4:1), T_5: Chickpea + barley (2:1), T_6: Chickpea + barley (4:1), T_7: Chickpea + oilseed rape (2:1), T_8: Chickpea + oilseed rape (4:1), T_9: Sole chickpea, T_{10}: Sole oats fodder, T_{11}: Sole linseed, T_{12}: Sole barley and T_{13}: Sole oilseed rape. The plant population of chickpea was kept same in all the treatments. The recommended doses of fertilizers for chickpea (15 kg N/ha and 20 kg P_2O_5/ha) were applied at the time of sowing. Variety PBG 7 of chickpea, OL 10 of oats fodder, LC 2063 of linseed, PL 807 of barley and GSC 6 of oilseed rape was used for sowing. The crops were sown simultaneously on 10th November during 2017 and on 5th November during 2018. Wheat bed planter was used for 67.5 cm apart spaced bed preparation (bed width was 37.5 cm and furrow width was 30 cm). Sowing of two rows of chickpea was done on the top of each bed and intercrops was sown in the furrows under 2:1 row ratio, whereas four rows of chickpea was sown on two beds and one row of intercrops was sown in furrows after two beds under 4:1 row ratio (Fig. 1). All cultural practices were followed as per recommendations. The manual harvesting of chickpea was done on 10th April, 2018 and 23rd April, 2019. Harvesting of oats fodder and barley was done at 60 DAS leaving stubble height of 6-8 cm from ground at first cut for uniform and quick re-growth of the crop and 2nd and 3rd cut of oats fodder was done at 90 and 120 DAS for green fodder. The harvesting of linseed, barley and oilseed rape was done before the harvest of chickpea crop. The harvested crop was tied into labelled bundles and kept for sun drying then threshing was carried out.

Growth parameters like plant height and dry matter accumulation were recorded at 30, 60, 90, 120 days after sowing (DAS) and at harvest. Other parameters like leaf area index, chlorophyll index and photosynthetically active radiation were recorded at 90, 120 DAS and at harvest. SPAD meter was used for measuring the chlorophyll index of leaves of intact plant.

Leaf area index was calculated as following:

$$\text{Leaf area index (LAI)} = \frac{\text{Total leaf area (cm}^2\text{)}}{\text{Total ground area (cm}^2\text{)}}$$

PAR interception was calculated as follows:

$$\text{PAR interception (\%)} = \frac{\text{PAR(I) - PAR (T) - PAR (R)}}{\text{PAR (I)}} \times 100$$

Where,

PAR (I) = Total PAR incoming above the canopy, Wm^{-2}

PAR (T) = PAR transmitted to ground, Wm^{-2}

PAR (R) = PAR reflected from the canopy, Wm^{-2}

The advantages of intercropping and the effect of competition between the component crops were evaluated using different competitive indices.

Land equivalent ratio (LER) calculated as following:

$$LER = LER_a + LER_b$$

$$LER_a = \frac{Y_{ab}}{Y_{aa}} \qquad LER_b = \frac{Y_{ba}}{Y_{bb}}$$

Where, LER_a and LER_b are the partial LER for crop 'a' and 'b' under intercropping system respectively; Y_{ab} and Y_{ba} are the yields of the two component crops when grown as intercrops; Y_{aa} and Y_{bb} are the yields per unit area when 'a' and 'b' grown as sole crops under those conditions with which comparison is to be made.

$$\text{Yield proportion of chickpea} = \frac{\text{LER chickpea}}{\text{LER}}$$

$$\text{Yield proportion of intercrop} = \frac{\text{LER intercrop}}{\text{LER}}$$

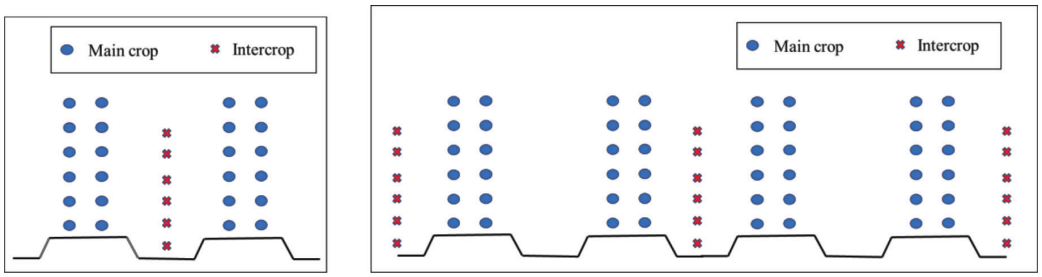


Fig. 1. Sowing of chickpea and intercrops in (a) 2:1 row ratio (b) 4:1 row ratio

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Area time equivalent ratio (ATER) calculated as following:

$$ATER = \frac{\{(L_a \times D_a) + (L_b \times D_b)\}}{T}$$

Where, L_a and L_b are the partial LER of component crops 'a' and 'b'; D_a and D_b indicates the duration of component crops a and b whereas T is the total duration of the intercropping system.

Aggressivity (A) calculated as following:

$$A_{ab} = \frac{Y_{ab}}{Y_{aa} \times Z_a} - \frac{Y_{ba}}{Y_{bb} \times Z_{ba}}$$

$$A_{ba} = \frac{Y_{ba}}{Y_{bb} \times Z_{ba}} - \frac{Y_{ab}}{Y_{aa} \times Z_{ab}}$$

Where, A_{ba} and A_{ab} are the aggressivity of crop 'a' and 'b' intercropped with 'b' and 'a'; Z_{ab} and Z_{ba} are the proportion of intercropped area initially allocated to crop 'a' and 'b' respectively. When A = zero, component crops are equally competitive. In any situation, both component crops have same numerical value but the sign for dominant component crop will be positive and the dominated crop will be negative.

Monetary advantage Index (MAI) calculated as described by Ghosh (2004).

$$MAI\ (Rs/ha) = \text{Commercial value of combined crops} \times \frac{LER - 1}{LER}$$

The data collected from the experiment was subjected to statistical test 'Analysis of variance technique' and critical difference (CD) values at 5% level of probability were computed for making comparison between treatments.

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RESULTS AND DISCUSSION

Plant height

Plant height is the basic index to indicate the plant development at a given time during the crop growth period. It is commonly used to distinguish the effect of different treatments on crop growth. Data on periodic plant height of chickpea was recorded at 30, 60, 90, 120 days after sowing (DAS) and at maturity (Table 1). The data showed that there was gradual increase in plant height with advancement of crop age during both the cropping seasons. There was an abrupt increase in plant height from 60 to 120 DAS but the increase was not uniform and the rate of increase in plant height decreased from 120 DAS to maturity. The data indicated that there was no significant difference in plant height among the treatments at all the stages of plant growth. Hence, the different intercropping systems failed to affect the plant height of chickpea. However, the highest plant height was recorded under chickpea + oilseed rape (2:1) followed by chickpea + oilseed rape (4:1) as compared to other treatments. This might be due to more competition for light and space and nature of plants to grow vertically when they were grown in association with closer planting in chickpea + oilseed rape intercropping system. Similar results were corroborated the findings of Sekhon *et al.* (2018) who reported that plant height was significantly influenced by the intercropping systems.

Dry matter accumulation

The periodic data on DMA at 30, 60, 90, 120 DAS and at harvest (Table 2) indicated that DMA increased continuously with the age of chickpea. During initial stages, there was slow growth and development of chickpea due to more competition by the intercrops.

Table 1. Plant height of bed planted chickpea as influenced by different intercropping systems

Treatment	Plant height (cm)									
	30 DAS		60 DAS		90 DAS		120 DAS		At harvest	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Chickpea + oats fodder (2:1)	8.6	8.5	21.7	21.1	46.9	50.3	68.5	69.2	74.0	72.8
Chickpea + oats fodder (4:1)	9.8	9.8	21.5	21.0	48.9	51.2	70.2	70.4	73.6	74.7
Chickpea + linseed (2:1)	8.8	9.6	21.4	22.3	47.1	48.7	68.2	69.3	72.6	74.4
Chickpea + linseed (4:1)	9.8	9.2	20.8	20.3	48.5	48.9	69.7	69.9	74.3	74.9
Chickpea + barley (2:1)	8.8	9.0	21.2	20.7	46.8	46.9	69.8	68.8	71.2	73.8
Chickpea + barley (4:1)	8.9	8.5	20.9	20.7	47.6	48.1	70.1	71.3	73.2	74.9
Chickpea + oilseed rape (2:1)	9.8	9.4	20.5	20.8	46.5	48.5	70.8	71.7	75.8	76.2
Chickpea + oilseed rape (4:1)	9.5	9.4	20.9	21.6	47.4	48.2	70.6	71.2	75.5	75.1
Sole chickpea	9.4	9.2	21.4	21.9	48.3	51.3	69.8	70.6	75.0	74.9
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 2. Dry matter accumulation (DMA) of bed planted chickpea as influenced by different intercropping systems

Treatment	DMA (q ha^{-1})									
	30 DAS		60 DAS		90 DAS		120 DAS		At harvest	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Chickpea + oats fodder (2:1)	2.66	2.54	7.99	8.63	28.3	28.2	45.4	46.3	59.1	60.4
Chickpea + oats fodder (4:1)	2.68	2.56	9.06	8.24	28.4	28.3	45.7	46.5	60.3	60.5
Chickpea + linseed (2:1)	2.61	2.60	8.16	8.44	26.4	26.4	42.2	42.4	53.7	52.4
Chickpea + linseed (4:1)	2.51	2.41	7.55	8.78	27.8	27.7	45.3	46.0	58.6	60.2
Chickpea + barley (2:1)	2.64	2.58	6.75	8.33	26.1	26.3	36.8	37.0	47.8	49.1
Chickpea + barley (4:1)	2.66	2.59	6.80	8.93	26.7	26.8	42.6	43.4	55.1	55.6
Chickpea + oilseed rape (2:1)	2.63	2.59	7.90	8.49	20.8	21.0	30.8	30.9	41.9	42.3
Chickpea + oilseed rape (4:1)	2.66	2.61	7.94	8.80	22.5	22.6	32.3	31.7	45.5	46.3
Sole chickpea	2.70	2.61	9.21	9.10	28.5	28.6	46.8	47.4	60.9	62.1
CD (P=0.05)	NS	NS	NS	NS	1.23	1.58	2.16	1.48	2.65	2.21

There was tremendous increase in rate of DMA from 90 DAS to maturity under all the intercropping systems. All the intercropping systems did not show any significant effect on DMA at 30 and 60 DAS but there was a significant difference from 90 DAS up to the harvest. The maximum dry matter accumulation was recorded in sole chickpea which might be due to lack of competition in the absence of intercrops for nutrients and moisture. At 90, 120 DAS and at harvest, the maximum dry matter accumulation was recorded in sole chickpea and statistically at par with chickpea + oats fodder (2:1), chickpea + oats fodder (4:1) and chickpea + linseed (4:1) row ratios but was significantly higher than all other treatments. Reduction in DMA may be due to the competition for soil moisture, nutrients and solar radiation for chickpea under different intercropping systems. The lowest dry matter accumulation was recorded in chickpea + oilseed rape (2:1) followed by chickpea + oilseed rape (4:1) row ratio due to adverse effect of oilseed rape on chickpea. Singh and Aulakh (2017) also reported that higher dry matter accumulation was recorded in sole chickpea than intercropping systems.

LAI, chlorophyll content and PAR interception

Data on leaf area index (LAI), chlorophyll index and photosynthetically active radiation (PAR) interception in leaves of chickpea was recorded at 60, 120 DAS and at harvest (Table 3). At 60 DAS of chickpea, LAI, chlorophyll index and PAR were not significantly influenced by different intercropping systems which might be due to less effect of intercrops on chickpea up to 60 DAS. But they were affected significantly at 120 DAS and at harvest during both the years. However, the maximum values of LAI (2.77 and 2.80), chlorophyll index (2.73 and 2.75) and PAR (82.0 and 82.8) were recorded at 120 DAS in sole chickpea which was statistically at par with chickpea + oats fodder (2:1), chickpea + oats

Table 3. Leaf area index (LAI), chlorophyll index and photosynthetically active radiation (PAR) interception by bed planted chickpea at 120 DAS as influenced by different intercropping systems

Treatment	LAI		Chlorophyll index		PAR interception (%)	
	2017	2018	2017	2018	2017	2018
Chickpea + oats fodder (2:1)	2.70	2.72	2.68	2.69	80.8	80.7
Chickpea + oats fodder (4:1)	2.72	2.75	2.72	2.74	80.8	81.1
Chickpea + linseed (2:1)	2.55	2.55	2.48	2.50	78.6	78.1
Chickpea + linseed (4:1)	2.64	2.68	2.62	2.63	80.6	80.4
Chickpea + barley (2:1)	2.54	2.56	2.37	2.39	77.4	77.5
Chickpea + barley (4:1)	2.60	2.62	2.54	2.55	79.1	79.5
Chickpea + oilseed rape (2:1)	2.07	2.10	2.28	2.29	72.1	72.4
Chickpea + oilseed rape (4:1)	2.18	2.20	2.35	2.36	74.0	74.3
Sole chickpea	2.77	2.80	2.73	2.75	82.0	82.8
CD (P=0.05)	0.15	0.14	0.13	0.13	2.83	2.59

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Table 4. Land equivalent ratio (LER), Area time equivalent ratio (ATER) and yield proportion in bed planted chickpea based intercropping systems

Treatment	LER		ATER		Yield proportion			
					Chickpea		Intercrop	
	2017	2018	2017	2018	2017	2018	2017	2018
Chickpea + oats fodder (2:1)	1.32	1.30	1.28	1.29	0.96	0.94	0.37	0.36
Chickpea + oats fodder (4:1)	1.24	1.22	1.18	1.15	0.99	0.98	0.25	0.24
Chickpea + linseed (2:1)	1.27	1.28	1.24	1.27	0.62	0.66	0.65	0.62
Chickpea + linseed (4:1)	1.23	1.21	1.23	1.21	0.85	0.87	0.37	0.34
Chickpea + barley (2:1)	1.06	1.09	1.04	1.08	0.59	0.59	0.47	0.50
Chickpea + barley (4:1)	1.16	1.12	1.15	1.12	0.89	0.84	0.26	0.28
Chickpea + oilseed rape (2:1)	0.96	0.94	0.93	0.91	0.19	0.34	0.77	0.60
Chickpea + oilseed rape (4:1)	0.93	0.99	0.91	0.97	0.39	0.49	0.54	0.50
Sole chickpea	1.00	1.00	1.00	1.00	1.00	1.00	-	-
CD (P=0.05)	0.11	0.17	0.15	0.18	-	-	-	-

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fodder (4:1) and chickpea + linseed (4:1) intercropping systems. LAI, chlorophyll content and PAR interception regularly increased up to 120 DAS due to maximum growth period of chickpea but declined at maturity due to senescence of the crop. The lower LAI, chlorophyll index and PAR were recorded under chickpea + oilseed rape (2:1) followed by chickpea + oilseed rape 4:1 row ratio which was due to more shading effect of oilseed rape on chickpea, but in contrast, Patel *et al* (2013) reported that LAI of main crop was not significantly influenced by the different intercropping systems.

Land equivalent ratio (LER), area time equivalent ratio (ATER) and yield proportion

In any intercropping system, higher LER indicates higher yield advantage over other intercropping treatments. LER was significantly influenced in different intercropping systems during both the years (Table 4). Among all the treatments, significantly higher LER was recorded in chickpea + oats fodder (2:1) system which was statistically at par with chickpea + oats fodder (4:1), chickpea + linseed (2:1) and chickpea + linseed (4:1) during both cropping seasons of 2017-18 and 2018-19. This might be due to the production of additional yield from intercrops over same land area and lower dominance of oats fodder on chickpea. Lowest values of LER was recorded in chickpea + oilseed rape (2:1) followed by chickpea + oilseed rape (4:1) which was attributed to the lower productivity of chickpea due to more competition under these cropping systems. Many studies revealed that higher LER was recorded with the intercropping systems and these results were supported by the findings of Torkaman *et al* (2018) and Singh *et al* (2019). Values of ATER were significantly influenced by different intercropping systems during the cropping seasons of 2017and 2018 (Table 4). Maximum ATER was recorded in chickpea + oats fodder (2:1) which was statistically at par with chickpea + oats fodder (4:1), chickpea + linseed (2:1), chickpea + linseed (4:1) and chickpea + barley (4:1) intercropping systems and

Table 5. Aggressivity (A) and monetary advantage index (MAI) in bed planted chickpea based intercropping systems

Treatment	Aggressivity				MAI (Rs/ha)	
	2017		2018		2017	2018
	Chickpea	Intercrop	Chickpea	Intercrop		
Chickpea + oats fodder (2:1)	0.31	-0.31	0.31	-0.31	25904.7	26478.4
Chickpea + oats fodder (4:1)	0.00	0.00	0.00	0.00	19612.4	20111.7
Chickpea + linseed (2:1)	-1.06	1.06	-0.90	0.90	20939.0	22762.1
Chickpea + linseed (4:1)	-0.80	0.80	-0.64	0.64	18342.7	18604.0
Chickpea + barley (2:1)	-0.53	0.53	-0.62	0.62	3823.4	6609.6
Chickpea + barley (4:1)	-0.21	0.21	-0.34	0.34	11733.4	10065.3
Chickpea + oilseed rape (2:1)	-2.19	2.19	-1.87	1.87	-3157.1	-5155.8
Chickpea + oilseed rape (4:1)	-2.07	2.07	-1.32	1.32	-5890.0	-407.9

significantly higher than all other treatments during both the years, due to better utilization of time and space. Lower values of ATER were recorded where chickpea was intercropped with oilseed rape with 2:1 or 4:1 planting pattern. This might be due to less utilization of time and space and also the adverse effect of oilseed rape on chickpea. Similar findings were reported by Poddar *et al* (2017) under different chickpea-spices intercropping systems. Yield proportion of chickpea in different intercropping systems was higher in chickpea + oats fodder in 2:1 row ratio. This might be due to the higher yield potential and less competitive ability. Yield proportion of intercrops was higher in oilseed rape as compared to other intercrops which might be due to the adverse and aggressive effect of oilseed rape on chickpea.

Aggressivity (A) and monetary advantage index (MAI)

Greater the numerical value, more will be the difference in competitive abilities and higher the differences between the actual and the expected yields. The results of aggressivity showed that chickpea acted as dominant species over oats fodder with positive values and dominated by all other intercrops under various intercropping systems. Chickpea under chickpea + oats fodder (2:1) system acted as a dominant crop during both the years. But in chickpea + oats fodder (4:1) system both the component crops were equally competitive. It means that chickpea was more aggressive in 2:1 row ratio with oats fodder and it was equally competitive in 4:1 row ratio with oats fodder. Maximum aggressivity values were recorded in oilseed rape as compared to other intercrops during both the cropping seasons of 2017 and 2018 thus showing more competitiveness with chickpea. Among the intercrops, oilseed rape crop was observed to be more competitive towards chickpea followed by linseed and barley. Poddar *et al* (2017) also reported similar findings. Chickpea + oats fodder in 2:1 row ratio recorded maximum monetary advantage index (MAI) followed by chickpea + linseed (2:1), chickpea + oats fodder (4:1) and chickpea + linseed (4:1) during both the cropping seasons of 2017-18 and 2018-19. This might be due to higher gross and net returns obtained under these intercropping systems. Lowest MAI was recorded in chickpea + oilseed rape in (2:1) system and it was followed by chickpea + oilseed rape (4:1) during both the years. The results corroborated the findings of Sharma *et al.* (2015) and Poddar *et al.* (2017) who also reported higher benefits in terms of MAI in different intercropping systems as compared to sole cropping.

Authors' contribution

Conceptualization and designing of the research work (MVP, KSS, TS); Execution of field/lab experiments and data collection (MVP, TS, KSS); Analysis of data and interpretation (MVP, TS, SS); Preparation of manuscript (MVP, KSS, TS).

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