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Allelopahtic effect of summer sunflower on germination, Emergence and vigour index of succeeding *kharif* mungbean (*Vigna radiata* L. Wilczek) under varied sowing periods: A pot experiment

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Abstract
Pot experiment was conducted during *kharif* season 2014 at Main Agricultural Research Station, UAS, Dharwad to know the allelopathic effect of summer sunflower on germination, emergence and vigour index of succeeding *kharif* mungbean (*Vigna radiata* L. Wilczek) under varied sowing periods**.** Seed germination (89.17 %) and vigour index (3167.58 at 20 DAS) were significantly higher in *kharif* mungbean sown in soil from summer fallow land (CS_2) over *kharif* mungbean sown in rhizosphere soil from summer sunflower grown plot (CS_1). Among the sowing periods, the crop sown after six weeks of harvest of sunflower (D_6) recorded significantly higher seed germination (92.50 %) and vigour index (3366.2 at 20 DAS) over others. The interaction of these two factors was also superior over others.

Keywords: Allelopathy, sunflower, mungbean, sowing periods, seedling vigour.

Introduction

Allelopathy has been increasingly recognized as an important ecological mechanism which influences plant dominance, succession and formation of plant communities, vegetation and crop productivity. It has been related to the problems with weed: crop interference (Bell and Koeppe, 1972) [3], phytotoxicity in stubble mulch farming (McCalla and Haskins, 1964) [11] and in certain types of crop rotations. Allelopathy is the direct or indirect influence of plants on one another through production of allelochemicals. These compounds are released by the plants through volatilization, leaching or decomposition of their residues (Rice, 1984; Miller, 1996) [13]. These substances have selective effects, depending upon their concentration, either inhibitory or stimulatory to the growth of comparison or subsequent crops or weeds (Cheema, 1988) [5]. Several phytotoxic substances causing germination and/or growth inhibitions have been isolated from plant tissues and soils. These substances are collectively known as allelochemicals. They are usually secondary plant products or waste products of main metabolic path ways of plants (Azania *et al.*, 2003) [2].

Sunflower (*Helianthus annuus* L.) is a strongly allelopathic plant (Hall *et al*, 1982) [9]. It is an annual oleaginous plant native to the Americas and it has allelopathic activity against some crops and weeds ((Bogatek *et al.*, 2006; Wilson and Rice, 1968; Ohno *et al.*, 2001) [4, 18, 17]. Sunflower is thermo and photo-insensitive, hence, it can be grown round the year in sub-tropics. Therefore, it fits well in the multiple cropping systems of these regions. In this species several substances with allelopathic properties such as phenolic compounds, diterpenes and triterpenes have been isolated and chemically characterized (Macias *et al.*, 1993) [10]. Crop residues of sunflower produce harmful effects on the germination and growth of subsequent crops (Nanjappa *et al*., 1999) [14]. Presently in India, sunflower is cultivated on an area of 8.20 lakh ha with the total production of 5.80 lakh tonnes and an average productivity of 707 kg ha^{-1} during 2012-13. In Karnataka, it is grown in area of 4.30 lakh ha with a production of 2.64 lakh tonnes and an average productivity of 613 kg ha^{-1} (Anon., 2013).

Mungbean or greengram (*Vigna radiata* L. Wilczek) is one of the important pulse crops in south and south-east Asia. In India, it is the third most important pulse crop after Bengal gram and pigeonpea. In India, it is covering an area of 3.53 m ha with a total production of 1.2 million tonnes and an average productivity of 340 kg ha^{-1}. Important greengram growing states in India are Odisha, Andhra Pradesh, Maharashtra, Karnataka, and Bihar. In Karnataka, it occupies an area of about 0.369 m ha with a total production of 0.042 million tonnes and an average productivity of only 231 kg ha^{-1} (Anon., 2013) [1]. Several studies indicated that sunflower is a well known allelopathic plant species and it has allelopathic effect on succeeding pulse crops (Narwal *et al.*, 1999a) [15]. It is observed that there is reduction in the yield of *kharif* mungbean by the allelopathic effect of summer sown sunflower. To address the issue that summer sunflower has allelopathic effect on *kharif* mungbean crop, to know the per cent reduction in germination and growth of mungbean seedlings by the allelopathic/residual effect of rhizosphere soil of rabi/summer sunflower and optimization of interval between sowing of mungbean and harvesting of sunflower to have minimum allelopathic effect.

Material and Methods

The pot experiment was conducted in laboratory conditions to study the allelopathic effect of summer sunflower on *kharif* mungbean under varied sowing periods in *vertisol*. Rhizosphere soils were collected from summer sunflower grown plot and fallow land and allelopathic study was conducted by taking soil (*vertisol*) of different cropping systems in pots and sowing of mungbean was done in that soil at weekly interval.

A pot experiment was conducted at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad (Karnataka). The Research Station comes under Northern Transition Zone (Zone-8) of Karnataka which lies between the Western Hilly Zone (Zone-9) and Northern Dry Zone (Zone -3) during *kharif*-2014. The soil used in this experiment was medium black clay soil. The composite soil sample of experimental area was collected before sowing and analyzed for important physical and chemical properties. The experimental soil was low in nitrogen (253.4 kg ha^{-1}), medium in phosphorous (27.7 kg ha^{-1}) and high in potash (325.84 kg ha^{-1}). The pot experiment was carried out in Completely Randomized Design with factorial concept (FCRD) replicated thrice with soil from different cropping systems as a one factor and sowing periods as another factor.

For the pot experiments, soils were collected from summer sunflower grown plot (CS_1) and fallow land (CS_2) and allelopathic study was conducted by taking soil (*vertisol*) of different cropping systems (CS) in pots and sowing of mungbean (D) was done in that soil at weekly interval (D_1- 14th June, D_2- 21th June, D_3- 28th June, D_4- 5th July, D_5-12th July and D_6-19th July) designated as CS_1D_1 to CS_2D_6, respectively. Twenty seeds were sown in each polythene pot of size (25cm height x 20 cm width) consisting different soil from different cropping system and germinated seedlings were counted. Observations were recorded at 5 days interval upto 20 days. Five normal seedlings were chosen for measuring shoot and root lengths and same seedlings were used to determine seedlings dry weight. The seedlings kept in butter paper bags were dried in hot air oven at 75±10^{0}C for 24 hours. After drying, they were cooled in a desiccator for 30 minutes and were weighed on a electronic balance. Their average weight was expressed in milligram per seedling for each treatment. For statistical analysis data were analyzed using analysis of variance and means were compared using critical difference at the 5 % probability (Gomez and Gomez, 1984) [8].

Results and Discussion

In the present pot experiment, attempts were made to know the allelopathic effect of sunflower on succeeding mungbean crop. Marked variations on per cent seed germination and growth of mungbean were observed due to soil from different cropping systems (CS) and sowing periods of mungbean (D).

Effect of soil of different cropping system (CS)

Mean germination per cent of mungbean was recorded significantly higher in kharif mungbean sown in soil from summer fallow land (CS_2-89.17 %) as compared to rhizosphere soil from summer sunflower grown plot (CS_1-80.56 %). This was around average of 8.61 % higher germination in CS_1 as compared to CS_2. There was no significant difference in the germination of mungbean sown in soil from summer fallow (CS_2) land (Fig. 1.). Since, there will be no influence of allelochemicals produced by the sunflower residues as in case of rhizosphere soil from summer fallow plot (CS_1). As the roots grow through the soil, at some points they may get in touch with decaying plant residues and are impacted by allelochemicals. Some of the toxic effects of decomposition products on plants are: inhibition of seed germination, stunted growth, and inhibition of the primary root system and increase in secondary roots, inadequate nutrient absorption, chlorosis; slow maturation and delay or failure of reproduction. Sunflower (*Helianthus annuus* L.) can actively influence the growth of surrounding plants due to its high allelopathic potential. These results were in conformity with findings of Azania *et al*. (2003) [2] and Dharmaraj *et al.* (1994b).

Table 1: Seed germination (%), shoot and root length (cm) of mungbean at different growth stages as influenced by soil from different cropping systems and sowing periods

Treatment	Seed germination (%)			Shoot length (cm)						Root length (cm)					
				15 DAS			20 DAS			15 DAS			20 DAS		
	CS_1	CS_2	Mean	CS_1	CS_2	Mean	CS_1	CS_2	Mean	CS_1	CS_2	Mean	CS_1	CS_2	Mean
D_1	71.67	86.67	79.17	10.95	13.03	11.99	13.10	15.20	14.15	16.49	17.76	17.13	18.63	19.95	19.29
D_2	75.00	86.67	80.83	11.50	13.19	12.35	13.67	15.30	14.49	16.60	17.96	17.28	18.71	20.10	19.41
D_3	78.33	88.33	83.33	11.95	13.29	12.62	14.05	15.28	14.67	16.92	17.82	17.37	19.03	20.03	19.53
D_4	80.00	88.33	84.17	12.25	13.32	12.79	14.37	15.33	14.88	17.32	18.05	17.69	19.50	20.12	19.81
D_5	86.67	91.67	89.17	12.90	13.38	13.14	14.93	15.40	15.13	17.70	17.89	17.80	19.85	20.32	20.09
D_6	91.67	93.33	92.50	13.33	13.47	13.40	15.46	15.57	15.52	18.09	18.22	18.15	20.07	20.49	20.28
Mean of CS	80.56	89.17		12.15	13.28		14.26	15.35		17.19	17.95		19.30	20.17	
For comparing means of	S.Em±	CD (P = 0.01)		S.Em±	CD (P = 0.01)		S.Em±	CD (P = 0.01)		S.Em±	CD (P = 0.01)		S.Em±	CD (P = 0.01)	
Soil from different cropping systems (CS)	1.19	4.73		0.06	0.23		0.07	0.26		0.05	0.19		0.06	0.24	
Sowing periods of mungbean (D)	2.07	8.19		0.10	0.39		0.11	0.45		0.09	0.34		0.10	0.41	
Interaction (CS x D)	2.93	NS		0.14	0.56		0.16	0.63		0.12	0.48		0.15	0.59	

CS: Different cropping systems (CS), **CS 1:** *Kharif* mungbean sown in previously summer sunflower grown plot, **CS 2:** *Kharif* mungbean sown in previously summer fallow land, **D:** Sowing period of mungbean, **D1:** One week after harvest of sunflower (14th June), **D2:** Two weeks after harvest of sunflower (21th June), **D3:** Three weeks after harvest of sunflower (28th June), **DAS:** Days after sowing NS: Non-significant, **D4:** Four weeks after harvest of sunflower (5th July), **D5**: Five weeks after harvest of sunflower (12th July), **D6:** Six weeks after harvest of sunflower (19th July)

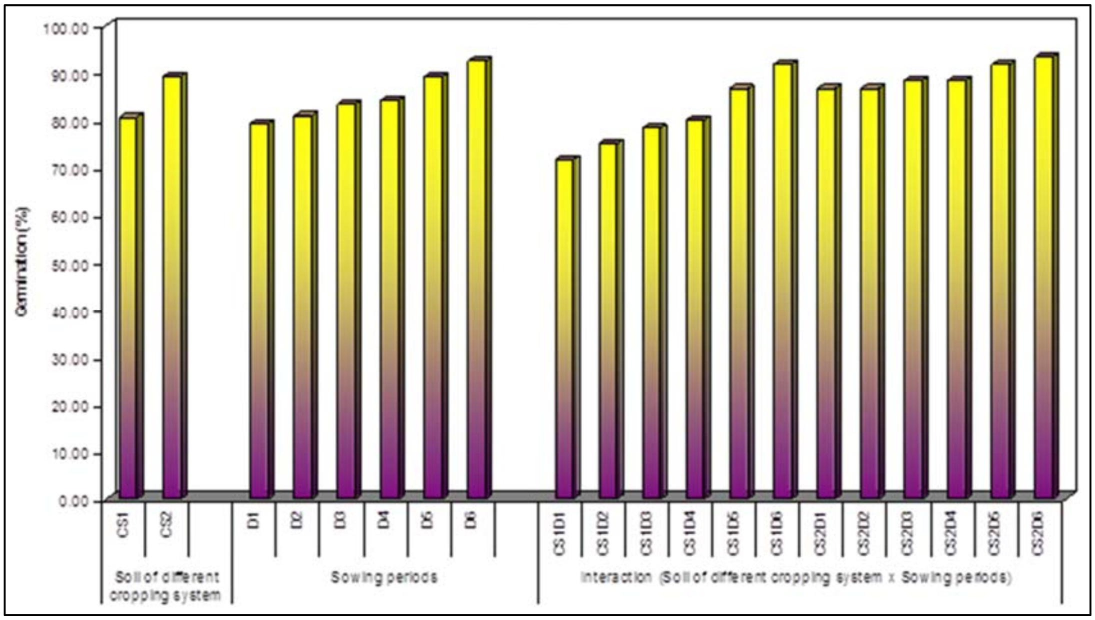

Fig 1: Seed gem ination (%) of mungbean at different growth stage as infiuenced by soil of different cropping systems and sowing periods

Growth parameter like mean seed germination (89.17 %), shoot length (13.28 and 15.35 cm), root length (17.95 and 20.17 cm), shoot dry weight (65.1 and 89.9 mg), root dry weight (19.3 and 23.8 mg) and vigour index (2785.42 and 31.67.58 at 15 and 20 DAS, respectively) was recorded significantly higher in CS_2 (*kharif* mungbean sown in soil from summer fallow land) over CS_1 (*kharif* mungbean sown in rhizosphere soil from previously summer sunflower grown plot) (Table 1, 2 and 3). Similar kinds of result were also reported by Mehboob *et al.* (2000) [12] in *Linum usitatissimum* and Ghafar *et al.* (2000) [7] in wheat.

As regard to growth parameters, growth parameters like shoot length, root length, shoot and root dry weight and seedling vigour index were significantly lower in CS_1 in all the four stages of the growth (5, 10, 15 and 20 DAS) as compared to CS_2. Reduced growth parameters in the pot having the rhizosphere soil from sunflower grown plot (CS_1) was mainly due to the allelochemicals produced by the sunflower residue in that rhizosphere soil either by volatilization, leaching and decomposition of sunflower plant residues. These produced allelochemicals inhibited the germination and growth parameters of mungbean, probably by affecting the cell division and elongation process that were very important at this stage or by interfering with enzymes involved in the mobilization of nutrients necessary for germination.

At 20 DAS, dehydrogenase activity showed significant difference between the soil from different cropping systems. *Kharif* mungbean sown in soil from summer fallow land (CS_2) recorded significantly higher dehydrogenase activity (33.9 µg TPF g^{-1} of soil day^{-1}) as compared to rhizosphere soil from summer sunflower grown plot (CS_1-22.1 µg TPF g^{-1} of soil day^{-1}).

Effect of sowing periods (D)

In the present investigation a progressive linear increasing trend was observed for growth parameters such as germination percentage, shoot length, root length, shoot and root dry weight and seedling vigour index as sowing period delayed [soil from summer sunflower grown plot after harvest of sunflower in (CS_1)].

Germination per cent of mungbean was significantly higher in mungbean sown after six weeks of harvest of sunflower) (D_6-92.50 %) over other sowing periods (79.17-84.17 %) except mungbean sown on five weeks after harvest of sunflower (D_5-89.17 %) with which it was on par (Fig. 1). This was followed by mungbean sown on four weeks after harvest of sunflower (D_4-84.17 %). Whereas, significantly lower germination (79.17 %) was observed in mungbean sown after one week of harvest of sunflower (D_1), which might be due to higher concentration of phenolic compounds in the soil. These compounds reduced gradually as delay in sowing periods.

Significantly higher values of growth parameters *viz.*, mean seed germination (92.50 %), shoot length (13.40 and 15.52 cm), root length (18.28 and 20.28 cm), shoot dry weight (64.9 and 90.0 mg), root dry weight (20.0 and 24.2 mg) and vigour index (2959.67 and 3366.2 at 15 and 20 DAS, respectively) were registered in *kharif* mungbean sown after six weeks of harvest of sunflower (D_6) over other sowing periods (Table 1, 2 and 3). This result was in conformity with the findings of Narwal *et al*. (1999b) [15].

Similarly, among the sowing periods, the crop sown after one week of harvest of sunflower (D_1) recorded significantly higher dehydrogenase activity (50.2 µg TPF g^{-1} of soil day^{-1}) over other sowing periods except crop sown after two weeks harvest of sunflower (D_2- 49.0 µg TPF g^{-1} of soil day^{-1}) with which it was on par. This was followed by three weeks after harvest of sunflower (D_3-32.5 µg TPF g^{-1} of soil day^{-1}).

On the contrary, increase in shoot length, root length, shoot and root dry weight and vigour index with increase in the sowing periods was observed in the soil from summer sunflower grown plot after harvest of sunflower in (CS_1) in all the four (5, 10, 15 and 20 DAS) stage (Fig. 2). This was

mainly due to gradual reduction in allelochemicals concentration in CS_1 from D_1 to D_6. There was reduction of allelochemicals in the rhizosphere region of the crop due to bio-degradation of allelochemicals and its difference from particular rhizosphere due to voltalization leaching and decomposition of sunflower residue.
Since, there was no impact of climate in the laboratory conditions. The seedlings in the *kharif* mungbean sown in soil from summer fallow land (CS_2) as they were exposed to similar kind of climate throughout the sowing periods; there was no significant difference among the sowing periods.

Effect of interaction (CS x D)
The interaction effects were significant difference in the growth parameters of mungbean which sown in the CS_1 system. All the growth parameters were significantly higher in CS_2 $D_{(1-6)}$ (*kharif* mungbean sown in soil from summer fallow to the date D_1 to D_6).

Table 2: Shoot and root dry weight (mg plant^{-1}) of mungbean at different growth stages as influenced by soil from different cropping systems and sowing periods

Treatment	Shoot dry weight (mg plant^{-1})						Root dry weight (mg plant^{-1})					
	15 DAS			20 DAS			15 DAS			20 DAS		
	CS_1	CS_2	Mean	CS_1	CS_2	Mean	CS_1	CS_2	Mean	CS_1	CS_2	Mean
D_1	59.1	64.7	61.9	81.5	88.5	85.0	17.0	19.1	18.0	20.2	23.6	21.9
D_2	60.1	64.6	62.4	82.9	88.9	85.9	17.5	19.2	18.4	21.1	23.8	22.4
D_3	61.6	64.7	63.2	84.3	90.0	87.1	18.2	19.1	18.6	21.5	23.3	22.4
D_4	62.1	65.2	63.7	86.0	89.8	87.9	18.4	19.0	18.7	22.2	23.5	22.9
D_5	63.5	65.6	64.6	88.4	90.9	89.7	18.9	19.6	19.2	23.1	24.2	23.6
D_6	64.0	65.7	64.9	88.8	91.2	90.0	19.9	20.1	20.0	23.9	24.6	24.2
Mean of CS	61.8	65.1		85.3	89.9		18.3	19.3		22.0	23.8	
For comparing means of	S.Em$\pm$	CD (P = 0.01)		S.Em$\pm$	CD (P = 0.01)		S.Em$\pm$	CD (P = 0.01)		S.Em$\pm$	CD (P = 0.01)	
Soil from different cropping systems (CS)	0.20	0.79		0.26	1.05		0.12	0.48		0.16	0.65	
Sowing periods of mungbean (D)	0.35	1.37		0.46	1.81		0.21	0.84		0.28	1.12	
Interaction (CS x D)	0.49	1.94		0.65	2.57		0.30	NS		0.40	1.59	

CS: Different cropping systems (CS), **CS_1:** *Kharif* mungbean sown in previously summer sunflower grown plot, **CS_2:** *Kharif* mungbean sown in previously summer fallow land, **D:** Sowing period of mungbean, **D_1:** One week after harvest of sunflower (14th June), **D_2:** Two weeks after harvest of sunflower (21th June), **D_3:** Three weeks after harvest of sunflower (28th June) **DAS:** Days after sowing **NS:** Non-significant, **D_4:** Four weeks after harvest of sunflower (5th July), **D_5:** Five weeks after harvest of sunflower (12th July),
D_6: Six weeks after harvest of sunflower (19th July)

Table 3: Seedling vigour index of mungbean at different growth stages as influenced by soil from different cropping systems and sowing periods

Treatment	Seedling vigour index						Dehydrogenase activity (µg TPF g^{-1} of soil day^{-1})		
	15 DAS			20 DAS					
	CS_1	**CS_2**	**Mean**	**CS_1**	**CS_2**	**Mean**	**CS_1**	**CS_2**	**Mean**
D_1	1966.17	2668.83	2317.50	2273.72	3045.53	2659.63	46.9	53.5	50.2
D_2	2108.10	2699.20	2403.65	2429.02	3067.77	2748.39	46.1	51.9	49.0
D_3	2261.52	2747.53	2504.53	2591.08	3118.17	2854.63	31.1	33.8	32.5
D_4	2365.67	2770.62	2568.14	2708.52	3133.18	2920.85	20.2	24.6	22.4
D_5	2652.15	2866.67	2759.41	3012.72	3274.65	3143.68	17.1	21.5	19.3
D_6	2880.25	2959.67	2919.96	3257.30	3366.20	3311.75	13.2	18.4	15.8
Mean of CS	2372.31	2785.42		2712.06	3167.58		22.1	33.9	
For comparing means of	S.Em$\pm$	CD (P = 0.01)		S.Em$\pm$	CD (P = 0.01)		S.Em$\pm$	CD (P = 0.01)	
Soil from different cropping systems (CS)	37.42	148.01		41.09	162.52		0.46	1.86	
Sowing periods of mungbean (D)	64.81	256.36		71.17	281.49		0.48	1.94	
Interaction (CS x D)	91.66	362.54		100.64	398.09		0.64	NS	

CS: Different cropping systems (CS), **CS_1:** *Kharif* mungbean sown in previously summer sunflower grown plot, **CS_2:** *Kharif* mungbean sown in previously summer fallow land, **D:** Sowing period of mungbean, **D_1:** One week after harvest of sunflower (14th June), **D_2:** Two weeks after harvest of sunflower (21th June), **D_3:** Three weeks after harvest of sunflower (28th June) **DAS:** Days after sowing **NS:** Non-significant, **D_4:** Four weeks after harvest of sunflower (5th July), **D_5:** Five weeks after harvest of sunflower (12th July), **D_6:** Six weeks after harvest of sunflower (19th July)

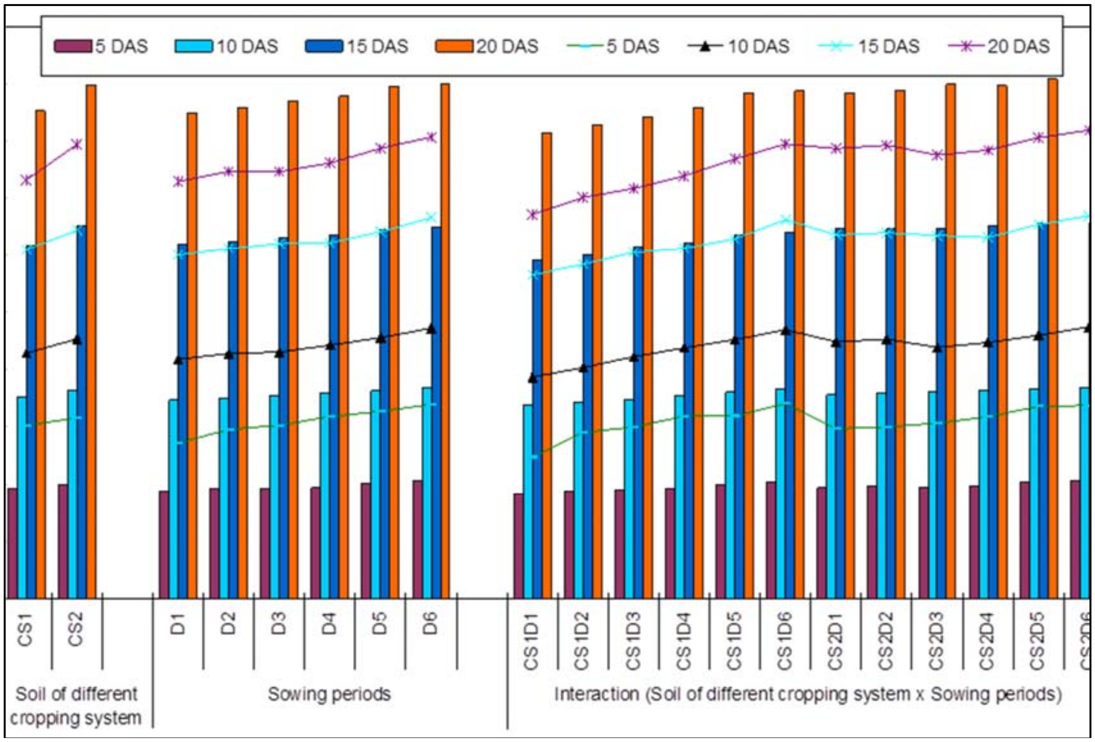

Fig 2: Shoot and root weight (mg plant^{-1}) of mungbean at different growth stages as infiuenced soil of different cropping systems and sowing periods

However, this was on par with last sowing period in CS_1D_6 (*kharif* mungbean sown in soil from summer fallow to the date of D_6) in all the growth stages (5, 10, 15 and 20 DAS). This might be due to sowing of mungbean at 5-6 weeks after harvest of sunflower; there was reduction in allelochemicals concentration in soil.

The treatment combination of CS_2D_6 (*kharif* mungbean sown in soil from summer fallow at the date of D_6) recorded significantly higher values of growth parameters like seed germination (93.33 %), shoot length (13.47 and 15.57 cm), root length (18.22 and 20.49 cm), shoot dry weight (65.7 and 91.2 mg), root dry weight (20.0 and 24.2 mg) and vigour index (2959.67 and 3366.2 at 15 and 20 DAS, respectively) over other treatment combinations (Table 1, 2 and 3). With respect to dehydrogenase activity, the statistically non-significant interaction effect was observed between soil from different cropping systems (CS) and sowing periods (D).

The interaction effect on treatment combinations consisting of CS_2D_{1-6} (*kharif* mungbean sown in soil from summer fallow to the date D_1 to D_6) was insignificant. This was mainly due to there was no influence of external climate on the growth of the seedlings *i.e.*, seedlings were exposed to similar condition of climate and soil throughout the growth stages of plants.

Conclusion

From the present study, it may be concluded that *kharif* mungbean sown after summer fallow at the date of D_1 (CS_2D_1) recorded significantly higher values of growth parameters, seedling dry weight and vigour index over other treatment combinations. This experiment results have given evidence that providing the 5-6 weeks gap between the sunflower harvest and sowing of next mungbean crop and this attributed to reducing the harmful allelopathic effects to provide the ambient growth conditions for the succeeding crops.

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