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Effect of weed management practices on growth and yield of pigeonpea [*Cajanus cajan* (L.) Millsp.] + soybean [*Glycine max* (L.) Merrill] intercropping system

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Abstract
A field experiment was carried out during *Kharif* 2016 at the Agricultural Research Station, Kalaburagi, University of Agricultural Sciences, Raichur to study the effect of weed management practices on growth and yield of pigeonpea and soybean intercropping system. The experiment consisted of pre and post-emergence herbicides *viz*., pendimethalin, imazethapyr, diclosulam and quizelofop-p-ethyl as sole application and in combination with cultural practice of hand weeding along with weed free check and unweeded control. The lowest weed density (0.71 m^{-2}), weed dry weight (0.71 m^{-2}) and higher weed control efficiency (100%) was recorded for weed free check. Followed by pendimethalin and imazethapyr coupled with hand weeding. Similarly, weed free check treatment recorded significantly higher plant height, dry matter accumulation and yields of pigeonpea and soybean (1512 kg ha^{-1} and 1188 kg ha^{-1} respectively) and B:C ratio was also highest in weed free check (3.46).

Keywords: intercropping, weed management, pigeonpea, soybean, herbicides

Introduction
Pigeonpea is an important pulse crop of the country. In Karnataka, pigeonpea is extensively grown in the northern part of the state. Soybean is considered as a wonder crop due to its dual qualities *viz*. high protein and oil content. This crop has gained considerable importance in the agricultural economy of the country. The pigeonpea and soybean intercropping system is becoming a highly remunerative cropping system in the northern transition dry zone belt of Karnataka. There are several constraints in the pigeonpea and soybean intercropping system one of them is weeds which often pose serious problems. Weeds compete with crop plants for moisture, nutrients, light and space. In addition, they also serve as an alternate host for several insect pests and diseases. Weed infestation during early stages in pigeonpea and soybean intercropping system is one of the major factors for loss in yield under assured rainfall conditions. The yield loss due to weed infestation in soybean was to the tune of 20-77 per cent (Muniyappa *et al*., 1986, Kurchania *et al.*, 2001) [5, 4] and in pigeonpea it was to the tune of 32-65 per cent (Vaishya and Khan, 1989, Kundra and Brar, 1990) [12, 3]. Slow growth habit of pigeonpea at initial stages encourages rapid growth of weeds and leads to severe crop weed competition which finally reduces the crop yield. The traditional method of weed control *viz*. intercultivation or hand weeding alone is laborious, expensive and insufficient. Moreover, complete weeding during critical crop growth stages is not possible due to increased cost and scarce availability of human labour. In addition, continuous rains during early crop growth stages in the northern dry transitional tract, hinder the cultural methods of weed control. Under such circumstances herbicides in combination with cultural practices offer economically suitable and effective control of weeds in pigeonpea and soybean intercropping system. Keeping these points in view the present study was undertaken to know the effect of weed management practices on weed control efficiency, growth and yield in pigeonpea and soybean intercropping system. The economic viability of the treatments was also worked out.

Material and Methods
The field study was undertaken at the Agricultural Research Station, Kalaburagi, University of Agricultural Sciences, Raichur during Kharif 2016 under assured rainfall situation. The experiment was laid out in randomized block design (RBD) with three replications and ten treatments. The treatments comprised of pre-emergence application of Pendimethalin @ 0.7 kg *a.i* ha^{-1}, Diclosulam @ 26 g *a.i* ha^{-1} and post-emergence application of Imazathpyr @ 75 g *a.i* ha^{-1}, Quizalofop-p-ethyl @ 25 g *a.i* ha^{-1} as well as the treatments in combination with one

hand weeding which were compared with weed free check and unweeded control. In case of weed free check, weeds were removed as and when they emerged. The experimental soil was black clay in texture belonging to the order *Vertisol* and pH was slightly alkaline (8.30) with an electrical conductivity of 0.41 d Sm^{-1} besides having a content of low soil organic carbon (0.49 %), soil was low in available nitrogen (232 kg ha^{-1}), medium in available phosphorus (29 kg ha^{-1}) and high in available potassium (430 kg ha^{-1}). All the package of practices except weed control was followed as per the recommendations.

The seeds of pigeonpea (cv.TS-3R) and soybean (cv, JS-335) were hand dibbled in 1:2 row proportion with 30 cm row spacing. The crop durations pigeonpea and soyben were 120 and 90 days, respectively. Pre-emergence herbicides were applied within 48 hours of sowing and post-emergence herbicides were applied at 25 DAS using knapsack sprayer fitted with WFN nozzle using spray volume of 1000 liters, as well as the treatments in combination with one hand weeding. The observations on weed count and weed dry weight were recorded at 30, 50 and 70 DAS. The plant height and dry matter accumulation was recorded at harvest of soybean and pigeonpea. Weed control efficiency (WCE) was calculated by the formula of Raman and Krishnamoorthy (2005) [8]. The economics of weed management practice was also worked out.

$$WCE\ (\%) = \frac{WCC - WCT}{WCC} \times 100$$

Where,

WCC = Dry weight of weeds in unweeded control plot

WCT = Dry weight of weeds in treated plot

Results and Discussion

Effect on weeds

At all the stages of the crop growth, the different weed populations (grasses, sedges, broad leaved and total weeds) and their total dry weight differed significantly. Significantly higher weed population and dry weight were recorded in weedy check when compared to rest of the treatments. This could be attributed to higher density and dry weight of grasses, sedges and broad leaved weeds. This season long interference of weed growth resulted in maximum utilization of resources such as moisture, nutrient, light and space. Various earlier workers (Prasad *et al*., 1985, Reddy *et al.* 2007 and Saudy and El Metwally 2009) [9, 10] also reported higher weed population and dry weight in unweeded check.

At all the stages of crop growth total dry weight of weeds differed significantly and were significantly higher in weedy check compared to rest of the treatments. This could be attributed to higher density of grasses, sedges, broad leaved weeds and total weed population (Table 1). This noninterference of weed growth resulted in maximum utilization of resources (moisture, nutrient, light and space) resulting in higher weed dry weight (Table 1). The highest weed density of 42.95, 52.90 and 75.50 per m^2 was noted in weedy check plot at 30, 50 and 70 DAS respectively as compared to weed free plot. This could possibly be ascribed to the severe competition for moisture, nutrients, space, light, shade and short life of weeds resulting in extermination of some species.

The weed dry matter production of 23.84 g m^{-2} recorded at 30 DAS under weedy check plot increased exponentially to 56.84 g m^{-2} at 50 DAS and 98.42 g m^{-2} 70 DAS. This increase in density and dry weight of weeds by a huge margin under weedy check plot might be attributed to uninterrupted growth of weeds coupled with greater competitive ability than crop that was almost suppressed due to profuse growth of weeds. Shinde *et al.* (2003) [11] reported similar kinds of results.

Further application of Pendimethalin 38.7 % CS @ 0.7 kg *a.i* ha^{-1} (PE) *fb* Imazathpyr @ 75 g *a.i* ha^{-1} at 20-25 DAS (POE) + HW at 45-50 DAS (T_3) and Pendimethalin 38.7 % CS @ 0.7 kg *a.i* ha^{-1} (PE) *fb* HW at 25 DAS and 45 DAS (T_4) recorded maximum WCE of 88.08 and 85.02 per cent, at 30 DAS, 85.52 and 82.86 per cent at 50 DAS and 90.70, 89.40 per cent at 70 DAS, respectively (Table 1). It is due to the selective combination of pre *fb* post-emergence herbicide in pigeonpea+ soybean intercropping which helped in controlling most of the grassy and broad leaved weeds. Hence, these treatments recorded maximum weed control efficiency at different stages of crop growth. Similar reports were also reported by Shinde *et al.* (2003) [11] and Nagaraju *et al*. (2009) [6].

Table 1: Total weed density, dry matter and weed control efficiency at various growth stages as influenced by weed management in pigeonpea + soybean intercropping system

Treatments	Total weed density m^{-2}			Total dry weight (g) of weeds (m^{-2})			Weed control efficiency (%)		
	30 DAS	50 DAS	70 DAS	30 DAS	50 DAS	70 DAS	30 DAS	50 DAS	70 DAS
T_1: Pendimethalin 38.7 % CS @ 0.7 kg *a.i* ha^{-1} (PE)	4.55 (20.20)	6.02 (35.83)	6.32 (39.52)	4.33 (18.27)	6.26 (38.76)	7.39 (54.17)	23.84	31.80	44.96
T_2: Imazathpyr 10% SL@ 75 g *a.i* ha^{-1} at 20-25 DAS (POE)	4.48 (19.64)	4.53 (20.03)	4.90 (23.57)	3.84 (14.25)	5.41 (28.86)	6.06 (36.23)	40.18	49.22	63.18
T_3: Pendimethalin 38.7 % CS @ 0.7 kg *a.i* ha^{-1} (PE) *fb* Imazathpyr10% SL@ 75 g *a.i* ha^{-1} at 20-25 DAS (POE) + HW at 45-50 DAS	2.63 (6.45)	2.47 (5.63)	3.65 (12.87)	1.82 (2.80)	2.95 (8.23)	3.10 (9.15)	88.08	85.52	90.70
T_4: Pendimethalin 38.7 % CS @ 0.7 kg *a.i* ha^{-1} (PE) *fb* HW at 25 DAS and 45 DAS	3.04 (8.75)	3.33 (10.59)	4.06 (15.99)	2.01 (3.57)	3.20 (9.74)	3.30 (10.43)	85.02	82.86	89.40
T_5: Diclosulam 84 WDG @ 26 g *a.i* ha^{-1} (PE) *fb* HW at 25 DAS and 45 DAS	4.13 (16.60)	4.57 (20.36)	4.79 (22.50)	2.52 (5.86)	4.67 (21.34)	5.35 (28.14)	75.41	63.05	71.40
T_6: Diclosulam 84 WDG @ 26 g *a.i* ha^{-1} (PE) *fb* Quizalofop-p-ethyl 5% EC @ 50g *a.i* ha^{-1} (POE) at 20-25 DAS + HW at 45-50 DAS	4.21 (17.28)	4.61 (20.80)	4.87 (23.25)	2.38 (5.18)	4.35 (18.45)	5.01 (24.65)	78.27	67.54	74.95
T_7: Pendimethalin 38.7 % CS @ 0.7 kg *a.i* ha^{-1} (PE) *fb* Quizalofop-p-ethyl 5% EC @ 50g a.i/ha (POE) at 20-25 DAS + HW at 45-50 DAS	3.62 (12.63)	4.08 (16.14)	3.92 (14.94)	2.17 (4.21)	3.79 (13.89)	4.02 (15.70)	82.34	75.56	84.04

T_8: Tank mix Imazathpyr 10% SL @ 35g *a.i* ha^{-1} (POE) + Quizalofop-p-ethyl @ 25 g *a.i* ha^{-1} (POE) at 20-25 DAS	4.37 (18.63)	4.81 (22.69)	5.34 (28.08)	3.46 (11.48)	5.15 (26.12)	5.74 (32.46)	51.80	54.04	67.01
T_9: Weed free	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (00.00)	0.71 (00.00)	0.71 (00.00)	100	100	100
T_{10}: Weedy check	6.59 (42.95)	7.30 (52.90)	8.71 (75.40)	4.93 (23.84)	7.57 (56.84)	9.94 (98.42)	00.00	00.00	00.00
S. Em. ±	1.12	1.84	1.63	0.41	0.61	1.02	3.08	3.67	4.90
C.D (P= 0.05)	3.37	5.51	4.90	1.22	1.84	3.06	9.16	11.02	14.69

DAS = Days after sowing, HD = Hand weeding, PE = Pre emergence, POE = Post emergence, *fb* = Followed by
* Figures in parenthesis indicate original values
Total weed count (x) data were transformed to $(x+0.5)^{1/2}$

Effect on crop growth and yield

Significantly higher plant height was observed in weed free check followed by Pendimethalin 38.7 % CS @ 0.7 kg *a.i* ha^{-1} (PE) *fb* Imazathpyr @ 75 g *a.i* ha^{-1} at 20-25 DAS (POE) + HW at 45-50 DAS and Pendimethalin 38.7 % CS @ 0.7 kg *a.i* ha^{-1} (PE) *fb* HW at 25 DAS and 45 DAS. Over the weedy check (Table 2).

The total dry matter produced by the pigeonpea and soybean under intercropping system in all the weed control treatments increased significantly compared to the weedy check due to reduced weed competition. The total dry matter produced in Pendimethalin 38.7 % CS @ 0.7 kg *a.i* ha^{-1} (PE) *fb* Imazathpyr @ 75 g *a.i* ha^{-1} at 20-25 DAS (POE) + HW at 45-50 DAS (T_3) and Pendimethalin 38.7 % CS @ 0.7 kg *a.i* ha^{-1} (PE) *fb* HW at 25 DAS and 45 DAS were significantly higher than the weedy check and are on par with each other in both the crops at all stages of crop, except in soybean at 30 DAS. This clearly indicates the intense competition between crop and weeds for growth resources resulting in maximum reduction of dry matter production in pigeonpea and soybean in weedy check and increased dry matter production under weed control treatments (Table 2). Similar results were also reported by earlier researchers (Habimana *et al.*, 2013) [2]. Among the weed control treatments, significantly higher seed yield (1512 and 1188 kg ha^{-1} of pigeonpea and soybean, respectively) was obtained with season long weed free check (T_9) compared with weedy check. However, it was on par with T_3-pendimethalin 38.7 % CS @ 0.7 kg *a.i* ha^{-1} (PE) *fb* Imazathpyr @ 75 g *a.i* ha^{-1} at 20-25 DAS (POE) + HW at 45-50 DAS. It was closely followed by T_4-Pendimethalin 38.7 % CS @ 0.7 kg *a.i* ha^{-1} (PE) *fb* HW at 25 DAS and 45 DAS (1398, 1351 and 1096, 1085 kg ha^{-1} of pigeonpea and soybean, respectively) and T_7-Pendimethalin 38.7 % CS @ 0.7 kg *a.i* ha^{-1} (PE) *fb* Quizalofop-p-ethyl 5% EC @ 50 g *a.i* ha^{-1} (POE) at 20-25 DAS + HW at 45-50 DAS (1345 and 953 kg ha^{-1} of pigeonpea and soybean, respectively).the next best higher yields treatments are T_6-Diclosulam 84 WDG @ 26 g *a.i* ha^{-1} (PE) *fb* Quizalofop-p-ethyl 5% EC @ 50 g *a.i* ha^{-1} (POE) at 20-25 DAS + HW at 45- 50 DAS and T_5-Diclosulam 84 WDG @ 26 g *a.i* ha^{-1} (PE) *fb* HW at 25 DAS and 45 DAS (1313,1298 and 912, 874 kg ha^{-1} of pigeonpea and soybean, respectively). The extent of yield increase in T_5, T_6, T_7, T_4, T_3 and T_2 was to the tune of 76, 75.2, 73.4, 73, 70.6, 65.3 and 68.8, 65.9, 63, 55.4, 54.8, 50.6 per cent of pigeonpea and soybean, respectively over the weedy check (Table 3). The superior performance of these treatments was mainly due to effective control of weeds since from sowing to maximum vegetative stage which created conditions similar to that of weed free environment due to combination of pre followed by post emergent application of the herbicides and smothering efficiency of intercrop. The effective reduction in weed growth in the above said treatments resulted in the reduced competition by the weeds for precious crop growth resources like nutrient, moisture, space and light and other available resource.

Significantly lowest B:C ratio was recorded in T_{10}-weedy check. This might be attributed to higher gross returns. However, in weed free check, the B: C ratio (3.46) was lesser even though the seed yield and gross returns were higher. This was due to higher cost of cultivation as a result of high cost incurred towards labour for weeding. Due to the severe crop weed competition throughout the crop growth period which ultimately resulted in decreased growth and yield contributing parameters, the unweeded control recorded significantly lowest B:C ratio (2.57) (Table 3). Shinde *et al*. (2003) [11] obtained higher benefit cost ratio (2.02) with pendimethalin @ 1.50 kg *a.i* ha^{-1} + one hand weeding at 40 DAS as compared to weedy check.

Table 2: Plant height and dry matter production of pigeonpea and soybean as influenced by weed management in pigeonpea + soybean intercropping system

Treatments		Plant height (cm)		Dry matter production (g plant^{-1})	
		At harvest		At harvest	
		P pea	Soy	P pea	Soy
T_1:	Pendimethalin 38.7 % CS @ 0.7 kg *a.i* ha^{-1} (PE)	150.11	42.27	129.66	18.27
T_2:	Imazathpyr 10% SL @ 75 g *a.i* ha^{-1} at 20-25 DAS (POE)	152.95	43.34	140.11	20.13
T_3:	Pendimethalin 38.7 % CS @ 0.7 kg *a.i* ha^{-1} (PE) *fb* Imazathpyr10% SL @ 75 g *a.i* ha^{-1} at 20-25 DAS (POE) + HW at 45-50 DAS	168.85	56.85	188.67	26.17
T_4:	Pendimethalin 38.7 % CS @ 0.7 kg *a.i* ha^{-1} (PE) *fb* HW at 25 DAS and 45 DAS	166.42	53.97	182.62	25.86
T_5:	Diclosulam 84 WDG @ 26 g *a.i* ha^{-1} (PE) *fb* HW at 25 DAS and 45DAS	159.35	45.66	153.57	22.42
T_6:	Diclosulam 84 WDG @ 26 g *a.i* ha^{-1} (PE) *fb* Quizalofop-p-ethyl 5 % EC @ 50g *a.i* ha^{-1} (POE) at 20-25 DAS + HW at 45- 50 DAS	161.03	47.34	158.21	23.00
T_7:	Pendimethalin 38.7 % CS @ 0.7 kg *a.i* ha^{-1} (PE) *fb* Quizalofop-p- ethyl 5 % EC @ 50g *a.i* ha^{-1} (POE) at 20-25 DAS + HW at 45-50 DAS	162.68	51.64	172.64	25.08
T_8:	Tank mix Imazathpyr 10% SL@ 35g *a.i* ha^{-1} (POE) + Quizalofop-p-ethyl @ 25 g *a.i* ha^{-1} (POE) at 20-25 DAS	158.70	43.86	147.83	21.54

T_9:	Weed free	176.25	58.43	200.91	26.89
T_{10}:	Weedy check	137.31	40.80	117.67	14.52
	S. Em. ±	5.41	0.81	6.12	0.60
	C.D (P= 0.05)	16.25	2.44	18.36	1.80

DAS = Days after sowing, HD = Hand weeding, PE = Pre emergence, POE = Post emergence, *fb* = Followed by
* Figures in parenthesis indicate original values
Total weed count (x) data were transformed to $(x+0.5)^{1/2}$

Table 3: Grain yield, straw yield and B:C ratio of pigeonpea and soybean as influenced by weed management in pigeonpea + soybean intercropping system

Treatments		Seed yield (kg ha^{-1})		Straw yield (kg ha^{-1})		B:C ratio
		P pea	Soy	P pea	Soy	
T_1:	Pendimethalin 38.7 % CS @ 0.7 kg *a.i* ha^{-1} (PE)	1103	724	2865	1432	2.87
T_2:	Imazathpyr 10% SL @ 75 g *a.i* ha^{-1} at 20-25 DAS (POE)	1142	793	2943	1496	2.94
T_3:	Pendimethalin 38.7 % CS @ 0.7 kg *a.i* ha^{-1} (PE) *fb* Imazathpyr10% SL @ 75 g *a.i* ha^{-1} at 20-25 DAS (POE) + HW at 45-50 DAS	1398	1096	3389	1910	3.38
T_4:	Pendimethalin 38.7 % CS @ 0.7 kg *a.i* ha^{-1} (PE) *fb* HW at 25 DAS and 45 DAS	1351	1085	3316	1943	3.21
T_5:	Diclosulam 84 WDG @ 26 g *a.i* ha^{-1} (PE) *fb* HW at 25 DAS and 45DAS	1298	874	3256	1624	2.89
T_6:	Diclosulam 84 WDG @ 26 g *a.i* ha^{-1} (PE) *fb* Quizalofop-p-ethyl 5 % EC @ 50g *a.i* ha^{-1} (POE) at 20-25 DAS + HW at 45- 50 DAS	1313	912	3291	1682	3.03
T_7:	Pendimethalin 38.7 % CS @ 0.7 kg *a.i* ha^{-1} (PE) *fb* Quizalofop-p- ethyl 5 % EC @ 50g *a.i* ha^{-1} (POE) at 20-25 DAS + HW at 45-50 DAS	1345	953	3304	1750	3.09
T_8:	Tank mix Imazathpyr 10% SL@ 35g *a.i* ha^{-1} (POE) + Quizalofop-p-ethyl @ 25 g *a.i* ha^{-1} (POE) at 20-25 DAS	1167	811	2987	1542	2.97
T_9:	Weed free	1512	1188	3578	2028	3.46
T_{10}:	Weedy check	987	601	2764	1427	2.54
	S. Em. ±	51	44	87	86	0.16
	C.D (P= 0.05)	152	133	261	260	0.49

DAS = Days after sowing, HD = Hand weeding, PE = Pre emergence, POE = Post emergence, *fb* = Followed by
* Figures in parenthesis indicate original values
Total weed count (x) data were transformed to $(x+0.5)^{1/2}$

Conclusion

It can be inferred from the present investigation that, application of pendimethalin 38.7 % CS @ 0.7 kg *a.i* ha^{-1} (PE) *fb* Imazathpyr @ 75 g *a.i* ha^{-1} at 20-25 DAS (POE) + HW at 45-50 DAS was the most effective weed control efficiency for controlling of weeds, obtaining higher plant height, growth, seed yield and B:C ratio in pigeonpea and soybean intercropping system under rainfed conditions of Karnataka.

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