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Productivity of Groundnut + Pigeonpea Relay Intercropping System as Influenced by Weed Management Options

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ABSTRACT

Background: Weed management is one of the most important agronomic constraints leading to severe losses in the cropping system. Intercropping has several advantages to mitigate the losses faced by monocropping in addition to which if there is a proper control of weeds then the advantages of the intercropping system can be multiplied.

Methods: An investigation was conducted on medium black clayey soils at Junagadh during *kharif* 2019-20 and 2020-21 in randomized block design with 10 treatments replicated thrice, to evaluate the effect of different weed management options on the growth and yield of groundnut + pigeonpea relay intercropping. The treatments were: pendimethalin 0.9 kg ha^{-1} as PE *fb* interculture and hand weeding at 45 DAS (T_1), pendimethalin 0.45 kg ha^{-1} + oxyfluorfen 0.09 kg ha^{-1} as PE *fb* interculture and hand weeding at 45 DAS (T_2), interculture and hand weeding at 15 DAS *fb* sodium acifluorfen 16.5% + clodinafop propargyl 8% (ready mix) 1 kg ha^{-1} at 45 DAS as POE (T_3), interculture and hand weeding at 15 DAS *fb* quizalofop p ethyl 40 g ha^{-1} at 45 DAS as POE (T_4), interculture and hand weeding at 15 DAS *fb* propaquizafop 70 g ha^{-1} at 45 DAS as POE (T_5), pendimethalin 0.9 kg ha^{-1} as PE *fb* sodium acifluorfen 16.5% + clodinafop propargyl 8% (ready mix) 1 kg ha^{-1} at 45 DAS as POE (T_6), pendimethalin 0.9 kg ha^{-1} as aPE *fb* quizalofop p ethyl 40 g ha^{-1} at 45 DAS as POE (T_7), pendimethalin 0.9 kg as ha^{-1} PE *fb* propaquizafop 70 g ha^{-1} at 45 DAS as POE (T_8), weed free (T_9) and unweeded control (T_{10}).

Result: The results of the experiment revealed that weed free registered significantly higher plant height, number of branches, dry matter per plant and number of root nodules per plant in groundnut and pigeonpea and was statistically on par with to intercultureand hand weeding at 15 DAS *fb* sodium acifluorfen 16.5% + clodinafop propargyl 8% (ready mix) 1 kg ha^{-1} at 45 DAS as PoE, pendimethalin 0.9 kg ha^{-1} as PE *fb* sodium acifluorfen 16.5% + clodinafop propargyl 8% (ready mix) 1 kg ha^{-1} at 45 DAS as PoE. The data on yield attributes and yield of both the crops depicted that significantly superior results were obtained with weed free treatment, which was statistically at par with intercultureand hand weeding at 15 DAS *fb* sodium acifluorfen 16.5% + clodinafop propargyl 8% (Ready mix) 1 kg ha^{-1} at 45 DAS as PoE and pendimethalin 0.9 kg ha^{-1} as PE *fb* sodium acifluorfen 16.5% + clodinafop propargyl 8% (Ready mix) 1 kg ha^{-1} at 45 DAS as PoE. While in case of groundnut equivalent pod and haulm yields, statistically superior yields were registered with weed free treatment, which was statistically at par with intercultureand hand weeding at 15 DAS *fb* sodium acifluorfen 16.5% + clodinafop propargyl 8% (Ready mix) 1 kg ha^{-1} at 45 DAS as PoE.

Key words: Clodinafop-propargyl, Hand weeding (HW), Interculture (IC), Oxyfluorfen, Pendimethalin, Propaquizafop, Quizalofop-p-ethyl, Sodium-acifluorfen.

INTRODUCTION

The most feasible approach to enhance crop yield is sowing and growing crops from beginning of monsoon season to post-monsoon season by adopting concept of relay intercropping system (AICRP, 2002-07). Groundnut contributes about 40 per cent to the total oilseeds production in the country (Sathyapriya *et al*., 2013). It is a leguminous crop, which fixes atmospheric nitrogen and covers the soil. While on the other hand, pigeonpea is a fast-growing crop with its extensive root system. Its deep tap root system allows optimum utilization of soil moisture and soil nutrients and can be an ideal crop in groundnut relay intercropping system and both the crops complement each other. Pigeonpea is used as a most preferred pulse crop by Indian rural and urban communities. Groundnut + pigeonpea is dominant cropping system, which helps to maintain the sustainability and profitability which form the major goals in the present world. Pigeonpea was sown a month after the groundnut crop was sown to reduce the competition between the crops and this may help increase of the yield. This practise is advocated and encouraged by the Pulses Research Station, JAU, Junagadh because of the erratic and scanty rainfall recived in the Saurashtra region making groundnut cultivation risky.

Weed management is an important agronomic aspect in crop production, as weed cause the highest percentage of damage to the crop and especially in dry regions where they compete with the crops for water, nutrients, CO_2 and light, ultimately reducing the crop yields to tune of 31%-

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59% (Singh *et al.*, 2020). The traditional practices of weed management *i.e.,* manual weeding is difficult to adopt in the present scenario with the growing labour scarcity and increasing labour wages. Mechanical weeding is difficult in intercropping as the intercrops may be damaged. Hence to reduce the risk and cost, chemical practices can be adopted along with the traditional practice of manual hand weeding. Thus, the crop may be put to advantage supressing the growth of weeds. This not only increases the yield but also reduces the cost of cultivation by decreasing the cost on additional labour utilised for manual weeding. The energy required for the crop production can also be reduced with the appropriate use of weed management practices. Finally, the productivity per unit land can be increased which increases the national income and accelerates the development of the nation. Thus, the proposal of doubling the farmers' income can be made true in a sustainable manner through crop intensification and diversification approach. Groundnut + pigeonpea relay intercropping system is the dominant intercropping system in Saurashtra region of Gujarat. But not much work has been done in the weed management aspect of groundnut + pigeonpea cropping system and especially in the relay intercropping of these crops.

MATERIALS AND METHODS

A field experiment was conducted at Instructional Farm, Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh (Gujarat) during *kharif* seasons of year 2019-20 and 2020-21. The soil of the experimental plot was clayey in texture, medium in organic carbon (0.62%), slightly alkaline in reaction with pH (8.32) and EC (0.286 dS m^{-1}). The soil was low in available nitrogen (270.20 kg ha^{-1}), medium in available phosphorus (28.2 kg ha^{-1}) and medium in available potash (251.7 kg ha^{-1}).

Additive series of intercropping in 2:1 ratio was adopted, wherein the main/base crop is groundnut and intercrop is pigeonpea. "GG 20" was groundnut variety used for this study as base crop, pigeonpea variety "GJP-1" as intercrop. The experiment was laid out in RBD with ten treatments, which were replicated thrice. The treatments comprised pendimethalin 0.9 kg ha^{-1} as PE *fb* IC+HW at 45 DAS (T_1), pendimethalin 0.45 kg ha^{-1} + oxyfluorfen 0.09 kg ha^{-1} as PE *fb* IC+HW at 45 DAS (T_2), IC+HW at 15 DAS *fb* sodium-acifluorfen 16.5% + clodinafop-propargyl 8% (Premix) 1 kg ha^{-1} at 45 DAS as POE (T_3), IC+HW at 15 DAS *fb* quizalofop-p-ethyl 40 g ha^{-1} at 45 DAS as POE (T_4), IC+HW at 15 DAS *fb* propaquizafop 70 g ha^{-1} at 45 DAS as POE (T_5), pendimethalin 0.9 kg ha^{-1} as PE *fb* sodium-acifluorfen 16.5% + clodinafop-propargyl 8% (Premix) 1 kg ha^{-1} at 45 DAS as POE (T_6), pendimethalin 0.9 kg ha^{-1} as PE *fb* quizalofop-p-ethyl 40 g ha^{-1} at 45 DAS as POE (T_7), pendimethalin 0.9 kg ha^{-1} as PE *fb* propaquizafop 70 g ha^{-1} at 45 DAS as POE (T_8), weed free (T_9) and unweeded control (T_{10}). The practices were adopted in accordance to the proposed treatments. Interculture in combination with hand weeding was carried in treatments 3, 4 and 5 at 15 DAS while in treatment 1 and 2 it was conducted at 45 DAS of groundnut. Pre emergence herbicide *viz.*, pendimethalin 30% EC and oxyfluorfen 23.5% EC was applied on the next day of sowing of groundnut and post emergence herbicides, quizalofop-p-ethyl, propaquizafop and sodium-acifluorfen + clodinafop-propargyl were applied at 45 DAS after intercultivation. The weed free was maintained clean with regular intercultivation and manual weeding. The unweeded control was left unweeding allowing the continuous growth of weeds. The spacing adopted was 60 cm × 10 cm for groundnut and 120 cm × 20 cm for pigeonpea to accomadate the row ratio of 2:1 and groundnut variety is semi spreading. The growth and yield attributes were recorded at harvest.

RESULTS AND DISCUSSION

Groundnut

Plant height

The weed free treatment (T_9) was found to be significantly superior in plant height (53.33, 54.57 and 53.95 cm in 2019-20, 2020-21 and pooled results, respectively) at harvest, which was statistically on par with treatments comprising IC+HW at 15 DAS *fb* sodium-acifluorfen 16.5% + clodinafop-propargyl 8% (Premix) 1 kg ha^{-1} at 45 DAS as PoE (T_3) and pendimethalin 0.9 kg ha^{-1} as PE *fb* sodium-acifluorfen 16.5% + clodinafop-propargyl 8% (Premix) 1 kg ha^{-1} at 45 DAS as PoE (T_6) in the year 2019-20, 2020-21 and pooled results. On the contrary, the unweeded control (T_{10}) recorded significantly the lowest plant height (36.63 cm, 39.70 cm and 38.17 cm in 2019-20, 2020-21 and pooled results, respectively) (Table 1).

Dry matter per plant

The weed free treatment (T_9) was noticed to be statistically superior in dry matter per plant at harvest (31.5, 30.1 and 30.8 g in 2019-20, 2020-21 and pooled results, respectively), which was on par with IC+HW at 15 DAS *fb* sodium-acifluorfen 16.5% + clodinafop-propargyl 8% (Premix) 1 kg ha^{-1} at 45 DAS as PoE (T_3) and pendimethalin 0.9 kg ha^{-1} as PE *fb* sodium-acifluorfen 16.5% + clodinafop-propargyl 8% (Premix) 1 kg ha^{-1} at 45 DAS as PoE (T_6) in 2019-20 and pooled results. In the second year, the weed free treatment (T_9) was found to be at par with treatments T_3 (IC+HW at 15 DAS *fb* sodium-acifluorfen 16.5% + clodinafop-propargyl 8% (Premix) 1 kg ha^{-1} at 45 DAS as PoE), T_6 (Pendimethalin 0.9 kg ha^{-1} as PE *fb* sodium-acifluorfen 16.5% + clodinafop-propargyl 8% (Premix) 1 kg ha^{-1} at 45 DAS as PoE), T_1 (Pendimethalin 0.9 kg ha^{-1} PE *fb* IC+HW at 45 DAS) and T_2 (Pendimethalin 0.45 kg ha^{-1} + oxyfluorfen 0.09 kg ha^{-1} PE *fb* IC+HW at 45 DAS). The unweeded control (T_{10}) recorded significantly the lowest dry matter per plant (17.2, 15.5 and 16.3 g) in 2019-20, 2020-21 and pooled results (Table 1).

Pigeonpea

Plant height

At harvest, significantly taller plants (202.4, 191.4 and 196.9 cm in 2019-20, 2020-21 and pooled results, respectively)

Table 1: Effect of various weed management practices on growth attributes at groundnut and pigeonpea harvest.

Treatment	Groundnut						Pigeonpea					
	Plant height (cm)			Dry matter per plant (g)			Plant height (cm)			Dry matter per plant (g)		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
T_1: Pendimethalin 0.9 kg ha^{-1} PE *fb* IC+HW at 45 DAS	46.64	46.90	46.77	27.0	26.2	26.6	178.4	164.8	171.6	102.3	98.1	100.2
T_2: Pendimethalin 0.45 kg ha^{-1} + oxyfluorfen 0.09 kg ha^{-1} PE *fb* IC+HW at 45 DAS	46.63	47.83	47.23	27.0	26.3	26.7	173.0	165.2	169.1	102.4	98.1	100.2
T_3: IC+HW at 15 DAS *fb* sodium-acifluorfen 16.5% + clodinafop-propargyl 8% (Premix) 1 kg ha^{-1} at 45 DAS as PoE	49.80	50.43	50.12	29.3	28.0	28.6	195.3	181.1	188.2	113.0	106.6	109.8
T_4: IC+HW at 15 DAS *fb* quizalofop-p-ethyl 40 g ha^{-1} at 45 DAS as PoE	46.62	47.43	47.03	25.3	23.8	24.5	164.6	154.3	159.5	98.4	90.1	94.2
T_5: IC+HW at 15 DAS *fb* propaquizafop 70 g ha^{-1} at 45 DAS as PoE	45.82	47.65	46.74	25.0	23.9	24.4	165.4	152.7	159.1	97.4	89.7	93.6
T_6: Pendimethalin 0.9 kg ha^{-1} PE *fb* sodium-acifluorfen 16.5% + clodinafop-propargyl 8% (Premix) 1 kg ha^{-1} at 45 DAS as PoE	49.83	50.47	50.15	29.3	27.3	28.3	190.6	180.9	185.7	112.4	104.4	108.4
T_7: Pendimethalin 0.9 kg ha^{-1} PE *fb* quizalofop-p-ethyl 40 g ha^{-1} at 45 DAS as PoE	46.57	47.40	46.98	24.6	23.7	24.1	165.1	153.4	159.3	98.2	90.0	94.1
T_8: Pendimethalin 0.9 kg ha^{-1} PE *fb* propaquizafop 70 g ha^{-1} at 45 DAS as PoE	46.80	47.57	47.18	25.1	23.9	24.5	166.4	152.4	159.4	98.4	89.3	93.8
T_9: Weed free	53.33	54.57	53.95	31.5	30.1	30.8	202.4	191.4	196.9	117.3	114.8	116.0
T_{10}: Unweeded control	36.63	39.70	38.17	17.2	15.5	16.3	128.5	107.2	117.8	77.3	67.3	72.3
S.Em.±	2.18	2.01	1.48	1.27	1.37	0.93	9.09	8.78	6.32	4.78	5.05	3.48
C.D. at 5%	6.47	5.98	4.25	3.77	4.06	2.68	27.02	26.09	18.13	14.21	15.01	9.97
C.V. %	8.05	7.26	7.66	8.42	9.52	8.96	9.11	9.49	9.29	8.14	9.22	8.67

were recorded with the weed free treatment (T_9) in both 2019-20, 2020-21 and pooled results and was statistically on par with IC+HW at 15 DAS *fb* sodium-acifluorfen 16.5% + clodinafop-propargyl 8% (Premix) 1 kg ha^{-1} at 45 DAS as PoE (T_3), pendimethalin 0.9 kg ha^{-1} as PE *fb* sodium-acifluorfen 16.5% + clodinafop-propargyl 8% (Premix) 1 kg ha^{-1} at 45 DAS as PoE (T_6) during the year 2019-20. Treatment T_9 (Weed free) was noticed to be statistically at par with T_3 and T_6 during 2020-21 and pooled results (Table 1). The unweeded control (T_{10}) recorded significantly the lowest plant height (128.5, 107.2 and 117.8 cm in 2019-20, 2020-21 and pooled results, respectively) in both years as well as pooled results.

Dry matter per plant

At harvest, the weed free treatment (T_9) recorded significantly greater crop dry matter per plant (64.5, 60.9 and 62.7 g in 2019-20, 2020-21 and pooled results, respectively) and was at par with IC+HW at 15 DAS *fb* sodium-acifluorfen 16.5% + clodinafop-propargyl 8% (Premix) 1 kg ha^{-1} at 45 DAS as PoE (T_3) and pendimethalin 0.9 kg ha^{-1} as PE *fb* sodium-acifluorfen 16.5% + clodinafop-propargyl 8% (Premix) 1 kg ha^{-1} at 45 DAS as PoE (T_6) during 2019-20, 2020-21 and pooled results. In 2019-20 and 2020-21, treatments T_3 (IC+HW at 15 DAS *fb* sodium-acifluorfen 16.5% + clodinafop-propargyl 8% (Premix) 1 kg ha^{-1} at 45 DAS as PoE) and T_6 (Pendimethalin 0.9 kg ha^{-1} as PE *fb* sodium-acifluorfen 16.5% + clodinafop-propargyl 8% (Premix) 1 kg ha^{-1} at 45 DAS as PoE) were found to be at par with pendimethalin 0.9 kg ha^{-1} as PE *fb* IC+HW at 45 DAS (T_1) and pendimethalin 0.45 kg ha^{-1} + oxyfluorfen 0.09 kg ha^{-1} as PE *fb* IC+HW at 45 DAS (T_2). Significantly lower crop dry matter per plant (35.5, 32.4 and 34.0 g in 2019-20, 2020-21 and pooled results, respectively) was recorded with the unweeded control (T_{10}) during both years and pooled data (Table 1).

Groundnut

Number of mature and immature pods per plant

The data on number of mature and immature pods per plant in groundnut are furnished in Table 2.

Number of mature pods

Significantly more number of mature pods per plant (11.86, 10.98 and 11.42 in 2019-20, 2020-21 and pooled results, respectively) was recorded with the weed free treatment (T_9) and it was at par with IC+HW at 15 DAS *fb* sodium-acifluorfen 16.5% + clodinafop-propargyl 8% (Premix) 1 kg ha^{-1} at 45 DAS as PoE (T_3) and pendimethalin 0.9 kg ha^{-1} as PE *fb* sodium-acifluorfen 16.5% + clodinafop-propargyl 8% (Premix) 1 kg ha^{-1} at 45 DAS as PoE (T_6) during both the years along with pooled results. However, treatments T_3 and T_6 were statistically on par with pendimethalin 0.9 kg ha^{-1} PE *fb* IC+HW at 45 DAS (T_1) and pendimethalin 0.45 kg ha^{-1} + oxyfluorfen 0.09 kg ha^{-1} as PE *fb* IC+HW at 45 DAS (T_2) during 2019-20 and 2020-21. Significantly lesser number of mature pods (6.29, 5.78 and 6.04 in 2019-20, 2020-21 and pooled results, respectively) was observed with the unweeded control (T_{10}) due to the heavy weed competition.

Pod yield

Significantly higher pod yield (1956, 1735 and 1846 kg ha^{-1} in 2019-20, 2020-21 and pooled results, respectively) was acquired by the weed free treatment (T_9), which was statistically on par with treatments *viz*., IC+HW at 15 DAS *fb* sodium-acifluorfen 16.5% + clodinafop-propargyl 8% (Premix) 1 kg ha^{-1} at 45 DAS as PoE (T_3) and pendimethalin 0.9 kg ha^{-1} PE *fb* sodium-acifluorfen 16.5% + clodinafop-propargyl 8% (Premix) 1 kg ha^{-1} at 45 DAS as PoE (T_6) in the year 2019-20, while in the second year and pooled data, the weed free treatment (T_9) was found to statistically at par with only T_3. However, T_3 was on par with T_6, T_1, T_2 during both the years as well as the pooled data. Conversely, the unweeded control (T_{10}) recorded significantly the lowest pod yield (585, 436 and 510 kg ha^{-1} in 2019-20, 2020-21 and pooled results, respectively).

Haulm yield

In the both the years (2019-20 and 2020-21) and pooled data, the weed free treatment (T_9) registered significantly higher groundnut haulm yield (3593, 2950 and 3271 kg ha^{-1} in 2019-20, 2020-21 and pooled results, respectively). The weed free treatment (T_9) was at par with IC+HW at 15 DAS *fb* sodium-acifluorfen 16.5% + clodinafop-propargyl 8% (Premix) 1 kg ha^{-1} at 45 DAS as PoE (T_3), pendimethalin 0.9 kg ha^{-1} as PE *fb* sodium-acifluorfen 16.5% + clodinafop-propargyl 8% (Premix) 1 kg ha^{-1} at 45 DAS as PoE (T_6) during 2019-20, 2020-21 and pooled results and in turn the treatment T_3 was at par with T_2 (Pendimethalin 0.45 kg ha^{-1} + oxyfluorfen 0.09 kg ha^{-1} as PE *fb* IC+HW at 45 DAS) and T_1 (Pendimethalin 0.9 kg ha^{-1} as PE *fb* IC+HW at 45 DAS). The unweeded control (T_{10}) recorded significantly the lowest haulm yield (1150, 823 and 987 kg ha^{-1} in 2019-20, 2020-21 and pooled results, respectively).

The effect of rainfall faded at the end of cropping season and clear-cut difference among the treatments was noticed in yield attributes and yield. The superior values in number of mature pods per plant, pod yield, haulm yield and lower values of number of immature pods per plant were registered with the weed free treatment, which was statistically at par with treatments T_3 and T_6. The zero competition from weeds under the weed free conditions might have resulted in the luxurious growth of the groundnut crop. The higher values of yield and yield attributes under herbicidal treatments could be attributed to increase in growth characters like plant height and dry matter per plant due to proper integration of weed management practices, which resulted in lower dry weight of weeds which is negatively correlated to the yield ultimately reducing the weed competition favouring the crop growth and productivity. The better plant growth and improved yield attributes finally led to higher dry pod, kernel and haulm yields. The effective weed control in critical crop

Table 2: Effect of various weed management practices on yield and yield attributes of groundnut and pigeonpea.

Treatment	Groundnut									Pigeonpea								
	Number of mature pods per plant			Pod yield (kg ha^{-1})			Haulm yield (kg ha^{-1})			Number of pods per plant			Seed yield (kg ha^{-1})			Stalk yield (kg ha^{-1})		
	2019	2019	2020	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
T_1: Pendimethalin 0.9 kg ha^{-1} PE *fb* IC+HW at 45 DAS	10.18	9.29	9.74	1582	1388	1485	3048	2535	2792	192.6	167.4	180.0	1678	1556	1617	2922	2625	2773
T_2: Pendimethalin 0.45 kg ha^{-1} + oxyfluorfen 0.09 kg ha^{-1} PE *fb* IC+HW at 45 DAS	10.13	9.38	9.76	1580	1396	1488	3076	2520	2798	187.6	170.9	179.2	1639	1333	1486	2788	2537	2663
T_3: IC+HW at 15 DAS *fb* sodium-acifluorfen 16.5% + clodinafop-propargyl 8% (Premix) 1 kg ha^{-1} at 45 DAS as PoE	11.14	10.40	10.77	1855	1601	1728	3333	2830	3081	210.5	188.1	199.3	1902	1704	1803	3314	2928	3121
T_4: IC+HW at 15 DAS *fb* quizalofop-p-ethyl 40 g ha^{-1} at 45 DAS as PoE	9.84	8.87	9.36	1341	1109	1225	2391	1984	2187	175.2	158.3	166.7	1497	1211	1354	2560	2316	2438
T_5: IC+HW at 15 DAS *fb* propaquizafop 70 g ha^{-1} at 45 DAS as PoE	9.86	9.05	9.45	1277	1064	1170	2409	1953	2181	175.5	154.5	165.0	1411	1185	1298	2524	2144	2334
T_6: Pendimethalin 0.9 kg ha^{-1} PE *fb* sodium-acifluorfen 16.5% + clodinafop-propargyl 8% (Premix) 1 kg ha^{-1} at 45 DAS as PoE	11.48	10.51	11.00	1769	1430	1600	3296	2682	2989	209.1	189.7	199.4	1787	1686	1737	3120	2832	2976
T_7: Pendimethalin 0.9 kg ha^{-1} PE *fb* quizalofop-p-ethyl 40 g ha^{-1} at 45 DAS as PoE	9.76	9.01	9.39	1262	1065	1163	2564	2073	2318	171.6	158.9	165.3	1248	997	1123	2255	1956	2106
T_8: Pendimethalin 0.9 kg ha^{-1} PE *fb* propaquizafop 70 g ha^{-1} at 45 DAS as PoE	9.72	9.04	9.38	1172	1018	1095	2677	2125	2401	175.3	158.0	166.7	1226	857	1042	2193	1787	1990
T_9: Weed free	11.86	10.98	11.42	1956	1735	1846	3593	2950	3271	223.2	201.5	212.3	2023	1861	1942	3549	3080	3314
T_{10}: Unweeded control	6.29	5.78	6.04	585	436	510	1300	952	1126	111.2	81.5	96.3	522	423	472	1201	1027	1114
S.Em.±	0.47	0.47	0.33	94	77	61	147	133	99	11.39	9.31	7.35	120	81	72	192	152	122
C.D. at 5%	1.39	1.40	0.96	279	228	174	436	394	283	33.83	27.66	21.09	356	242	208	570	450	351
C.V. %	8.11	8.87	8.47	11.30	10.85	11.15	9.18	10.15	9.63	10.77	9.90	10.41	13.88	11.02	12.78	12.58	11.30	12.07

growth period of 2-8 weeks (Tewari *et al.,* 1989) was observed especially in these treatments leading to enhanced photosynthetic activity and partitioning of assimilates, resulting in improved yield attributes and yield. The sowing of pigeonpea crop for every two lines of groundnut helped to remove the prevailing weeds in those lines and slow growth of the pigeonpea facilitated the good growth of the groundnut.

The lowest values of the yield attributes (number of mature pods per plant), pod yield, haulm yield were registered with the unweeded control (T_{10}). This might be due to the shorter plant height, lower number of branches and lower dry matter per plant owing the competition faced by the crop for moisture, light, nutrients and CO_2 due to the uncontrolled weeds. The results of the present investigation strongly support the findings of Reddy and Reddy (2004); Kushwah and Vyas (2005); Dutta *et al.* (2005); Madhavi *et al.* (2008); Kalhapure *et al.* (2013); Yadav *et al.* (2014); Dixit *et al.* (2016); Haque *et al.* (2016) and Vora *et al.* (2019).

Pigeonpea

Number of pods per plant

Significantly higher number of pods per plant (223.2, 201.5 and 212.3 in 2019-20, 2020-21 and pooled results, respectively) in pigeonpea was recorded with the weed free treatment (T_9) and it was statistically equivalent to IC+HW at 15 DAS *fb* sodium-acifluorfen 16.5% + clodinafop-propargyl 8% (Premix) 1 kg ha^{-1} at 45 DAS as PoE (T_3) and pendimethalin 0.9 kg ha^{-1} as PE *fb* sodium-acifluorfen 16.5% + clodinafop-propargyl 8% (Premix) 1 kg ha^{-1} at 45 DAS as PoE (T_6) in both the years along with pooled results. During 2019-20, the weed free treatment (T_9) was also statistically at par with pendimethalin 0.9 kg ha^{-1} PE *fb* IC+HW at 45 DAS (T_1). Treatments T_3 and T_6 were statistically at par with pendimethalin 0.9 kg ha^{-1} PE *fb* IC + HW at 45 DAS (T_1) and pendimethalin 0.45 kg ha^{-1} + oxyfluorfen 0.09 kg ha^{-1} as PE *fb* IC+HW at 45 DAS (T_2) during 2019-20, 2020-21 and pooled results. Significantly lower number of pods per plant was recorded with the unweeded control (111.2, 81.5 and 96.3 in 2019-20, 2020-21 and pooled results, respectively) during 2019-20, 2020-21 along with pooled results.

Seed yield

The weed free treatment (T_9) registered significantly higher seed yield (2023, 1861 and 1942 kg ha^{-1} in 2019-20, 2020-21 and pooled results, respectively), which was observed to be statistically on par with IC+HW at 15 DAS *fb* sodium-acifluorfen 16.5% + clodinafop-propargyl 8% (Premix) 1 kg ha^{-1} at 45 DAS as PoE (T_3), pendimethalin 0.9 kg ha^{-1} as PE *fb* sodium-acifluorfen 16.5% + clodinafop-propargyl 8% (Premix) 1 kg ha^{-1} at 45 DAS as PoE (T_6) and pendimethalin 0.9 kg ha^{-1} as PE *fb* IC+HW at 45 DAS (T_1) during the first year, while in the second year and pooled data, it was statistically at par with T_3 and T_6. However, T_1 was statistically on par with second best treatment, T_3 during 2020-21 and pooled results. On the other hand, the unweeded control (T_{10}) recorded significantly lowest seed yield (522, 423 and 472 kg ha^{-1} in 2019-20, 2020-21 and pooled results, respectively).

Stalk yield

The weed free treatment (T_9) registered significantly higher stalk yield (3549, 3080 and 3314 kg ha^{-1} in 2019-20, 2020-21 and pooled results, respectively) and was at par with IC+HW at 15 DAS *fb* sodium-acifluorfen 16.5% + clodinafop-propargyl 8% (Premix) 1 kg ha^{-1} at 45 DAS as PoE (T_3), pendimethalin 0.9 kg ha^{-1} as PE *fb* sodium-acifluorfen 16.5% + clodinafop-propargyl 8% (Premix) 1 kg ha^{-1} at 45 DAS as PoE (T_6) during 2019-20, 2020-21 and pooled data. Pendimethalin 0.9 kg ha^{-1} as PE *fb* IC+HW at 45 DAS (T_1) and pendimethalin 0.45 kg ha^{-1} + oxyfluorfen 0.09 kg ha^{-1} as PE *fb* IC+HW at 45 DAS (T_2) were found to be statistically at par with T_3 and T_6 during 2019-20 and 2020-21. The unweeded control (T_{10}) recorded significantly the lowest stalk yield (1201, 1027 and 1114 kg ha^{-1} in 2019-20, 2020-21 and pooled results, respectively).

The crop under weed free conditions attained optimum growth possibly due to elimination of weeds from inter and intra rows besides better aeration due to manipulation of surface soil and thus, more space, moisture, light and nutrients were available for the better growth and development, which resulted into superior yield attributes and consequently the highest seed and stalk yields. Among the herbicidal treatments, application of pendimethalin as pre-emergence curbed the establishment of initial flush of weeds and initial interculturealong with hand weeding at 15 DAS removed all the established weed flora and maintained a clean environment around the crop. Application of the ready-mix herbicides at 45 DAS helped to control the mixed weed flora providing a competitive advantage to the crop. The sowing of pigeonpea crop in between the rows of groundnut also helped in removal of the weeds and the groundnut crop acted as a mulch for pigeonpea crop in the later stages curbing the weed growth.

Significantly the lowest values of the yield attributes pod yield, haulm were recorded with the unweeded control (T_{10}). The severe competition due to unrestricted growth of weeds in this treatment might have inhibited the growth of the crop leading to the inhibited yield attributes, seed and stalk yields. Similar findings were obtained by Srivastava *et al.* (2004); Singh (2007); Shete *et al.* (2009); Murali *et al.* (2013); Goud and Patil (2014); Malik and Yadav (2014); Harithavardhini *et al.* (2016); Kathirvelan (2017) and Sai and Tigga (2018).

Groundnut pod equivalent yield

The data on groundnut pod equivalent yield are presented in Table 3. The weed free treatment (T_9) was significantly superior in groundnut equivalent pod yield 4261, 3856 and 4058 kg ha^{-1} in 2019-20, 2020-21 and pooled results, respectively) during both the years as well as pooled results. It was found to be statistically at par with IC+HW at 15 DAS *fb* sodium-acifluorfen 16.5% + clodinafop-propargyl 8%

Table 3: Effect of various weed management practices on groundnut pod and haulm equivalent yield.

Treatment	Groundnut pod equivalent yield (kg ha^{-1})			Groundnut haulm equivalent yield (kg ha^{-1})		
	2019	2020	Pooled	2019	2020	Pooled
T_1: Pendimethalin 0.9 kg ha^{-1} PE *fb* IC+HW at 45 DAS	3495	3161	3328	3048	2535	2792
T_2: Pendimethalin 0.45 kg ha^{-1} + oxyfluorfen 0.09 kg ha^{-1} PE *fb* IC+HW at 45 DAS	3447	2915	3181	3076	2520	2798
T_3: IC+HW at 15 DAS *fb* sodium-acifluorfen 16.5% + clodinafop-propargyl 8% (Premix) 1 kg ha^{-1} at 45 DAS as PoE	4022	3542	3782	3333	2830	3081
T_4: IC+HW at 15 DAS *fb* quizalofop-p-ethyl 40 g ha^{-1} at 45 DAS as PoE	3047	2488	2768	2391	1984	2187
T_5: IC+HW at 15 DAS *fb* propaquizafop 70 g ha^{-1} at 45 DAS as PoE	2885	2414	2650	2409	1953	2181
T_6: Pendimethalin 0.9 kg ha^{-1} PE *fb* sodium-acifluorfen 16.5% + clodinafop-propargyl 8% (Premix) 1 kg ha^{-1} at 45 DAS as PoE	3806	3351	3578	3296	2682	2989
T_7: Pendimethalin 0.9 kg ha^{-1} PE *fb* quizalofop-p-ethyl 40 g ha^{-1} at 45 DAS as PoE	2684	2201	2443	2564	2073	2318
T_8: Pendimethalin 0.9 kg ha^{-1} PE *fb* propaquizafop 70 g ha^{-1} at 45 DAS as PoE	2568	1995	2282	2677	2125	2401
T_9: Weed free	4261	3856	4058	3593	2950	3271
T_{10}: Unweeded control	1179	918	1049	1300	952	1126
S.Em.±	133	117	89	147	133	99
C.D. at 5%	396	349	255	436	394	283
C.V. %	7.35	7.58	7.47	9.18	10.15	9.63

(Premix) 1 kg ha^{-1} at 45 DAS as PoE (T_3) and further, this treatment (T_3) was statistically equivalent to pendimethalin 0.9 kg ha^{-1} as PE *fb* sodium-acifluorfen 16.5% + clodinafop-propargyl 8% (Premix) 1 kg ha^{-1} at 45 DAS as PoE (T_6) in 2019-20, 2020-21. In pooled data, the weed free treatment (T_9) was significantly superior over all other treatments and T_3 and T_6 were at par with each other which were found to be the next best treatments. The unweeded control (T_{10}) due to heavy weed competition recorded significantly the lowest groundnut pod equivalent yield (1179, 918 and 1049 kg ha^{-1} during 2019-20, 2020-21 and pooled results, respectively).

Groundnut haulm equivalent yield

Significantly higher groundnut haulm equivalent yield (3593, 2950 and 3271 kg ha^{-1} in 2019-20, 2020-21 and pooled results, respectively) was recorded with the weed free treatment (T_9) during both the years as well as pooled results. IC+HW at 15 DAS *fb* sodium-acifluorfen 16.5% + clodinafop-propargyl 8% (Premix) 1 kg ha^{-1} at 45 DAS as PoE (T_3) and pendimethalin 0.9 kg ha^{-1} as PE *fb* sodium-acifluorfen 16.5% + clodinafop-propargyl 8% (Premix) 1 kg ha^{-1} at 45 DAS as PoE (T_6) were statistically equivalent with each other and also with T_9 (Weed free) during 2019-20, 2020-21 and pooled data. Pendimethalin 0.9 kg ha^{-1} as PE *fb* IC+HW at 45 DAS (T_1) and pendimethalin 0.45 kg ha^{-1} + oxyfluorfen 0.09 kg ha^{-1} as PE *fb* IC+HW at 45 DAS (T_2) were recorded to be statistically at par with T_6, T_3 in the three cases. The unweeded control (T_{10}) due to heavy weed competition recorded significantly the lowest groundnut haulm equivalent yield (1300, 952 and 1126 kg ha^{-1} in 2019-20, 2020-21 and pooled results, respectively).

Under weed free conditions, both the crops might have had a luxuriant growth supplementing each other by their nitrogen fixing capacity and hence, ultimately resulting in superior yield of both crops and also groundnut equivalent yield. In weed management treatments, it might be due to timely and effective control of weeds right from germination of crops by intercultivation coupled with post-emergence herbicides which provided weed free environment to the groundnut and pigeonpea resulted in higher yields than other treatments (Bhagyashree *et al*., 2018). The sowing of the pigeonpea in between the lines of groundnut after a month had mulching effect along with removing the weeds in those lines. The results of this study confirmed the earlier findings of Tomar *et al.* (2004); Singh *et al.* (2005); Pardeshi *et al.* (2008); Kumawat (2013) and Khazi *et al.* (2018).

CONCLUSION

On the basis of the results obtained from the two-year field investigation, it could be concluded that higher yield along with effective weed management in *kharif* groundnut + pigeonpea relay intercropping under South Saurashtra Agro-climatic Zone can be achieved by IC+HW at 15 DAS followed by sodium-acifluorfen 16.5% + clodinafop-propargyl 8% (Premix) 1 kg ha^{-1} at 45 DAS without any phytotoxic effect on both the crops.

Conflict of interest: None.

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