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INFLUENCE OF PLANT POPULATION AND WEED MANAGEMENT PRACTICES ON YIELD AND ECONOMICS OF *RABI* PIGEON PEA (*CAJANUS CAJAN* (L.) MILLSP)

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Abstract- A field experiment was conducted during the *rabi* seasons of 2012-13 and 2013-14 to study the bio-efficacy of various herbicides on weeds, yield and economics of pigeon pea. The predominant weed flora were *Sorghum halepense, Echinochloa crus-galli and Cynodon dactylon L.* among monocot; *Cyperus rotundus* L. among sedges; and *Amaranthus viridis L., Digera arvensis and Portulaca oleracea, Physalis minima, Euphorbia hirta, Corchorus olitorus and Alternenthara sessili* among dicot. Significantly the lowest weed population and dry weight of weeds were recorded with a plant population of 83,333 plants/ha. Significantly higher grain (1043 kg/ha) and stalk (2734 kg/ha) yields with net returns of 29,452 Rs/*ha* and benefit: cost ratio of 3.13 were recorded with a plant population of 41,666 plants/ha and remained at par with plant population of 55,555 plants/ha. The lowest dry weight of weeds (407.05 kg/ha) and weed control efficiency (79.64 %) at harvest were recorded in weed free check which produced, the highest yield of grain (1200 kg/ha) and stalk (3319 kg/ha). An application of pendimethalin @ 1 kg/ha + hand weeding at 40 days after sowing was remunerative in pigeon pea as it had given the higher net return (33211 Rs/ha) and benefit: cost ratio (3.03).

Keywords- Hand Weeding, Pendimethalin, Plant population, Pigeon pea.

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Introduction

Pigeon pea is one of the major grain legume (pulse) crops of the tropics and subtropics, endowed with several unique characteristics. It finds an important place in the cropping system adopted by small farmers in a number of developing countries. Although, globally pigeon pea ranks sixth in an area and production in comparison to other grain legumes such as beans, peas and chickpeas. Considering the above facts and views, the present experiment was planned to study the effect of plant population and weed management on pigeon pea production. The yield of pigeon pea is limited by a number of factors such as agronomic, pathogenic, entomological, genetic and their interaction with environment. Among different agronomic practices, choice of a suitable geometry (plant population) and weed management practices are important factors, limiting the yield. Long duration pigeon pea can adjust to a wide range of population. Therefore, the major challenge for farmers is effective weed management, to harvest maximum yield. Manual removal of weeds is labour intensive, tedious, back breaking and does not ensure weed removal at critical stage of crop-weed competition due to non-availability of labours, and sometimes bad weather condition which does not allow labourers to move in the field. In such situation herbicides are more effective in controlling the weeds besides reducing the total energy requirement for pigeon pea cultivation. Pre-emergence application of herbicides mainly control weeds in the earlier stages and weeds emerging at later stages of growth are not controlled effectively. Hence, the present investigation was undertaken to study the alone and sequential application of herbicides on weed flora, yield, nutrient uptake by weeds and crop, and economics in pigeon pea under different plant populations.

MaterialsandMethods

A field experiment was conducted during *rabi* seasons of the two consecutive years of 2012-13 and 2013-14 at College Farm, Navsari Agricultural University, Navsari Campus, Navsari (Gujarat) situated between 20′ 57′ N latitude, 72° 54′ E longitude and has an altitude of about 10 m above mean sea level (amsl). The soil of the experimental field was clayey in texture, having pH 7.6 and 7.7 in first and second year, respectively, low in available nitrogen (213.52, 215.20 kg ha^{-1}, in first and second year, respectively), medium in available phosphorus (30.91, 30.98 kg ha^{-1}, in first and second year, respectively) and fairly rich in available potassium (367.60, 365.28 kg ha^{-1}, in first and second year, respectively) with slightly alkaline reaction. In general, weather conditions were favorable for plant growth and no severe pest and diseases noticed during both the years of experimentation. Total twenty-four treatment combinations consisting of three plant populations *viz.* 83,333 plants/ha (P_1)' 55,555 plants/ha (P_2) and 41,666 plants/ha (P_3) and eight weed management practices *viz.* (W_1) Unweeded control, (W_2) Weed free (HW at 20 and 40 DAS), (W_3) Pendimethalin @ 1 kg ha^{-1} as pre-emergence (PE), (W_4) Imazethapyr @ 75 g ha^{-1} (POE) at 20 DAS, (W_5) Quizalofop ethyl @ 40 g ha^{-1} (POE) at 20 DAS, (W_6) Pendimethalin @ 1 kg ha^{-1} (PE) + Imazethapyr @ 75 g ha^{-1} (POE) at 40 DAS, (W_7) Pendimethalin @ 1 kg ha^{-1} (PE) + Quizalofop ethyl @ 40 g ha^{-1} (POE) at 40 DAS and (W_8) Pendimethalin @ 1 kg ha^{-1} + hand weeding at 40 DAS were evaluated in factorial randomized block design with three replications. The experimental plots were 7.2 m long and 4.0 m wide, laid out according to factorial randomized block design. The land was irrigated first followed by two ploughings (including operation with disc plough, cultivator and rotavator) to make a fine seed bed. Pigeon pea *cv.* 'GT-102' was used for manual sowing. Before sowing seeds were treated with @ Rhizobium 250 g/10 kg of seeds and sown evenly. The crop was fertilized with recommended dose of fertilizer (25:50:00 kg N:P_2O_2:K_2O kg/ha). The shallow furrows were opened manually in each plot as per treatments and entire quantity of phosphorous (40 kg P_2O_2/ha) in the form of single super phosphate and 100% dose of nitrogen (25 kg N/ha) in the form of urea were manually applied uniformly before sowing of pigeon pea crop in both the years. The package of recommended practices was adopted to maintain the crop. Immediately after sowing of the seed a light irrigation was given to the crop for uniform germination. Post emergence herbicide were applied

using Knapsack sprayer fitted with flat fan nozzle attached with the hood of sprayer by mixing in 500 L of water/ha as per treatments. Besides a light irrigation just after sowing, crop received four post-sowing irrigations during both the years of experimentation. Data on weed population were recorded at 30 days after sowing. The observations on weed density and their dry matter were taken randomly from 1.0 m^2 quadrate from net plot area from each treatment. Economic analysis was done on the basis of prevailing market prices of inputs used and the output obtained from each treatment. Sale prices of output (Rs/kg) were: pigeon pea grain, 40.00; pigeon pea straw, 1.00; input price (Rs/kg): pigeon pea seed, 120; urea, 12.65; SSP , 31.25; herbicides (Rs/litre): pendimethalin, (405); quizalofop ethyl, (1550); imazethapyr, (1749); labour wage, (120/man/day).The data were analysed separately for year 2012-13 and 2013-14 and individual year's data were subjected to pooled analysis to obtain a trend among results over the years.

Results and Discussion

Weeds

The prominent weed flora observed in the weedy plot of the experiment was *Echinochloa crusgalli* L. and *Cynodon doctylon* L. among monocot; *Cyperus rotundus* L. among sedges; and *Amaranthus viridis L., Digera arvensis and Portulaca oleracea, Physalis minima, Euphorbia hirta, Corchorus olitorus and Alternenthara sessili* among dicot weeds during both the years of investigation.

The effect of plant population on monocots at 30 DAS was found to be non-significant. While, significant effect in pooled results in dicot and sedges weeds and total weed population [Table-1]. Similar trend was followed in case of dry weight of weeds at 40 DAS and harvest. However, significantly higher weed population and dry weight of weeds were recorded with plant population of 41,666 plant/ha. This might be due to more space provided in lower plant population leading to luxurious growth of weeds in these treatments resulted in the higher dry matter accumulation by weeds, while higher plant population recorded the lowest dry weight of weeds due to better crop stand in higher plant population causing smothering effect on weeds growth.

Table-1 *Weed population/m^2, dry weight of weeds at 40 DAS & at harvest, weed control efficiency and weed index in pigeon pea influenced by various treatments of plant population and weed management (Pooled)*

Treatments	Weed population/m^2 at 30 DAS				Dry weight of total weeds (kg/ha)		WCE (%)		WI (%)
	Monocot	Dicot	Sedges	Total	At 40 DAS	At harvest	At 40 DAS	At harvest	
Plant population (P)									
P_1: 83,333 plants ha^{-1} (60cm x 20cm)	3.34 (11.00)	2.67 (7.13)	2.86 (9.11)	4.54 (25.36)	16.66 (306.56)	17.81 (348.71)	-	-	-
P_2: 55,555 plants ha^{-1} (90cm x 20cm)	3.47 (11.86)	3.01 (8.95)	3.30 (11.42)	4.89 (29.87)	18.09 (350.59)	19.03 (389.54)	-	-	-
P_3: 41,666 plants ha^{-1} (120cm x 20cm)	3.50 (12.14)	3.07 (9.34)	3.36 (11.82)	4.96 (30.86)	18.65 (370.50)	19.48 (407.05)	-	-	-
S.Em.±	0.06	0.06	0.06	0.07	0.23	0.20	-	-	-
C.D. (P=0.05)	NS	0.16	0.17	0.20	0.65	0.57	-	-	-
Weed management practices (W)									
W_1: Unweeded control	4.41 (19.10)	3.94 (15.08)	5.42 (29.05)	6.32 (57.24)	28.85 (840.28)	30.02 (908.22)	-	-	59.37
W_2: Weed free (HW at 20 & 40 DAS)	2.81 (7.58)	2.04 (3.92)	2.17 (4.62)	3.72 (15.16)	11.85 (142.14)	13.78 (189.64)	83.08	79.11	-
W_3: Pendimethalin @ 1 kg ha^{-1} (PE)	3.44 (11.51)	2.83 (7.78)	3.08 (9.24)	4.74 (26.62)	17.82 (319.71)	19.92 (398.28)	61.95	56.14	17.94
W_4: Imazethapyr @ 75 g ha^{-1} (POE) at 20 DAS	3.64 (12.84)	3.14 (9.55)	3.44 (11.56)	5.11 (31.57)	20.11 (404.89)	21.98 (483.42)	51.81	46.77	28.10
W_5: Quizalofop ethyl @ 40 g ha^{-1} (POE) at 20 DAS	3.44 (11.49)	3.34 (10.81)	3.60 (12.63)	5.12 (32.32)	18.73 (352.12)	20.73 (430.73)	58.09	52.57	25.18
W_6: W_3 + Imazethapyr @ 75 g ha^{-1} (POE) at 40 DAS	3.47 (11.63)	2.64 (6.61)	2.52 (6.12)	4.59 (23.10)	15.69 (248.27)	15.28 (235.80)	70.45	74.02	10.18
W_7: W_3 + Quizalofop ethyl @ 40 g ha^{-1} (POE) at 40 DAS	3.22 (10.00)	2.81 (7.57)	2.78 (7.55)	4.54 (23.56)	14.85 (222.26)	14.42 (209.80)	73.54	76.89	8.75
W_8: Pendimethalin @ 1 kg ha^{-1} (PE) + HW at 40 DAS	3.07 (9.16)	2.59 (6.48)	2.36 (5.51)	4.26 (20.01)	14.52 (210.75)	14.08 (198.27)	74.91	78.16	4.92
S.Em.±	0.10	0.10	0.10	0.12	0.38	0.33	-	-	-
C.D. (P=0.05)	0.18	0.16	0.17	0.20	0.65	0.57	-	-	-
C.V. %	12.66	13.85	9.08	8.12	9.01	7.44	-	-	-
Interaction	NS	NS	NS	NS	NS	NS	-	-	-

Note: Figure in parenthesis refers to actual weed population and those outside are $\sqrt{X+0.5}$ transformed values

Looking to weed management, weed free (HW at 20 & 40 DAS) (W_2) did not crub the density of weeds because weeding was done at 20 days after sowing, whereas dry weight of weeds at 60 days after sowing and at harvest was significantly the lowest with this treatment. However, marked reduction in density was observed in plot receiving pre-emergence application of @ Pendimethalin 1.0 kg/ha coupled with hand weeding at 40 DAS (W_8) followed by application of pre-emergence Pendimethalin 1.0 kg/ha followed by Quizalofop ethyl @ 40 g ha^{-1} (POE) at 40 DAS (W_7) and found superior than other treatments. Identical increase in weed control efficiency was noted with treatment weed free check through two hand weedings at 20 and 40 days after sowing (W_2) followed by Pendimethalin 1.0 kg/ha coupled with hand weeding at 40 DAS (W_8) and Pendimethalin 1.0 kg/ha followed by Quizalofop ethyl @ 40 g ha^{-1} (POE) at 40 DAS (W_7), respectively. Contrary to this lowest weed index was observed with weed free check (W_2) followed by Pendimethalin 1.0 kg/ha + hand weeding at 40 days after sowing (W_4) and Pendimethalin 1.0 kg/ha followed by Quizalofop ethyl @ 40 g ha^{-1} (POE) at 40 DAS (W_7)**.** This is due to lower weed population and reduced dry matter production of weeds during initial stage and effective control of Yield data [Table-3] revealed that among plant population, pigeon pea growing with plant population of 41,666 plants ha^{-1} (P_3) produced significantly higher grain yield which was 14.45 and 20.12% higher than higher and medium plant population of 55,555 and 41,666 plants /ha, respectively. The higher grain yield in lower plant population was the result of better weed control efficiency and higher later on emerged weeds through hand weeding which ultimately provided weeds free environment to pigeon pea crop.

Different plant populations and weed control treatments significantly influenced the N, P and K uptake (kg/ha) by weeds [Table-4]. Pigeon pea indicated that uptake of N, P_2O_5 and K_2O were found significantly higher with plant population at 41,666 plants ha^{-1} (P_3), closely followed by 55,555 plants ha^{-1} (P_2). All the herbicidal treatments significantly reduced the N-P-K uptake by weeds than weedy check. The highest uptake of nutrients (N, P_2O_5 and K_2O) by pigeon pea was observed under Weed free (HW at 20 & 40 DAS) (W_2), while unweeded plots recorded the lowest value. The removal of nutrients through weeds was the lowest in weed free treatments.

Crop

The highest yield attributes *viz.* number of seeds/pod, number of pods/plant and test weight were recorded in pigeonpea, mainly due to the lowest weed dry weight and the highest weed control efficiency obtained from Weed free (HW at 20 & 40 DAS) being on par with pendimethalin *fb* hand weeding at 40 DAS [Table-2]. yield attributes. The findings are in agreement with the findings of Parameswari *et al.* (2003)[1]**.**

Maximum grain yield (1200 kg/ha) was recorded under Weed free (HW at 20 & 40 DAS) which was on par with pendimethalin 1 kg/ha as pre-emergence + H.W. at 40 DAS (1141 kg/ha). This might be attributed to marked improvement in dry

Table-2 *Growth and yield attributes of pigeon pea at harvest by various treatments of plant population and weed management (Pooled)*

Treatments	Plant height (cm)	Number of branches plant^{-1}	days to 50 % flowering	Dry matter production (g plant^{-1})	No. of pods plant^{-1}	No. of seeds pods^{-1}	Test weight (g)
Plant population (P)							
P_1: 83,333 plants ha^{-1} (60cm x 20cm)	100.52	13.15	80.65	54.03	79.87	3.63	109.58
P_2: 55,555 plants ha^{-1} (90cm x 20cm)	90.02	15.01	86.06	60.47	87.84	3.57	110.34
P_3: 41,666 plants ha^{-1} (120cm x 20cm)	86.33	15.67	87.70	63.26	92.84	3.72	110.55
S.Em.±	1.39	0.23	1.11	0.69	1.32	0.07	1.15
C.D. (P=0.05)	3.90	0.66	3.13	1.95	3.72	NS	NS
Weed management practices (W)							
W_1: Unweeded control	70.93	10.35	77.11	38.19	55.55	2.94	105.63
W_2: Weed free (HW at 20 & 40 DAS)	100.96	16.24	92.29	67.93	101.14	3.91	111.78
W_3: Pendimethalin @ 1 kg ha^{-1} (PE)	94.07	15.42	86.78	62.07	88.89	3.68	111.29
W_4: Imazethapyr @ 75 g ha^{-1} (POE) at 20 DAS	91.25	14.00	76.16	55.04	79.34	3.56	109.73
W_5: Quizalofop ethyl @ 40 g ha^{-1} (POE) at 20 DAS	92.53	14.50	78.71	59.14	82.60	3.63	109.73
W_6: W_3 + Imazethapyr @ 75 g ha^{-1} (POE) at 40 DAS	93.21	15.42	87.60	62.69	94.51	3.78	109.92
W_7: W_3 + Quizalofop ethyl @ 40 g ha^{-1} (POE) at 40 DAS	96.69	15.28	89.08	63.62	95.90	3.75	111.41
W_8: Pendimethalin @ 1 kg ha^{-1} (PE) + HW at 40 DAS	98.69	15.68	90.70	65.36	96.87	3.89	111.77
S.Em.±	2.26	0.38	1.82	1.13	2.16	0.12	1.89
C.D. (P=0.05)	3.90	0.66	3.13	1.95	3.72	0.20	NS
C.V. %	10.40	11.12	9.08	8.12	10.54	13.60	7.26
Interaction	NS	NS	NS	NS	NS	NS	NS

Table-3 *Yield and economics of pigeon pea at harvest by various treatments of plant population and weed management (Pooled)*

Treatments	Yield (kg/ha)		Cost of production (Rs/ha)	Gross realization (Rs/ha)	Net realization (Rs/ha)	BCR
	Grain	Stalk				
Plant population (P)						
P_1: 83,333 plants ha^{-1} (60cm x 20cm)	868	2442	12193	35940	21300	2.43
P_2: 55,555 plants ha^{-1} (90cm x 20cm)	993	2621	11533	41045	27065	2.91
P_3: 41,666 plants ha^{-1} (120cm x 20cm)	1043	2734	11173	43072	29452	3.13
S.Em.±	14.63	33.30	-	-	-	-
C.D. (P=0.05)	41.15	93.69	-	-	-	-
Weed management practices (W)						
W_1: Unweeded control	487	1503	8233	20245	8612	1.75
W_2: Weed free (HW at 20 & 40 DAS)	1200	3319	13033	49644	33211	3.03
W_3: Pendimethalin @ 1 kg ha^{-1} (PE)	984	2385	8758	40564	27431	3.10
W_4: Imazethapyr @ 75 g ha^{-1} (POE) at 20 DAS	862	2082	10102	35541	22039	2.64
W_5: Quizalofop ethyl @ 40 g ha^{-1} (POE) at 20 DAS	898	2165	9553	36983	24030	2.87
W_6: W_3 + Imazethapyr @ 75 g ha^{-1} (POE) at 40 DAS	1077	3064	10627	44631	29629	2.98
W_7: W_3 + Quizalofop ethyl @ 40 g ha^{-1} (POE) at 40 DAS	1095	3114	9958	45341	30888	3.15
W_8: Pendimethalin @ 1 kg ha^{-1} (PE) + HW at 40 DAS	1141	3163	11158	47205	31672	3.05
S.Em.±	23.88	54.38	-	-	-	-
C.D. (P=0.05)	41.15	93.69	-	-	-	-
C.V. %	10.47	8.88	-	-	-	-
Interaction	NS	NS	-	-	-	-

Table-4 *Uptake of nitrogen, phosphorus and potash by total weeds as influenced by various treatments of plant population and weed management*

Treatments	N uptake (kg ha^{-1})			P uptake (kg ha^{-1})			K uptake (kg ha^{-1})		
	1st Year	2nd Year	Pooled	1st Year	2nd Year	Pooled	1st Year	2nd Year	Pooled
Plant population (P)									
P_1: 83,333 plants ha^{-1} (60cm x 20cm)	5.57	5.71	5.64	2.48	2.47	2.47	7.58	7.87	7.72
P_2: 55,555 plants ha^{-1} (90cm x 20cm)	6.34	6.32	6.33	2.76	2.70	2.73	8.43	8.57	8.50
P_3: 41,666 plants ha^{-1} (120cm x 20cm)	6.53	6.52	6.52	2.81	2.86	2.83	8.58	8.74	8.66
S.Em.±	0.17	0.16	0.12	0.06	0.08	0.05	0.19	0.21	0.14
C.D. (P=0.05)	0.49	0.47	0.33	0.18	0.22	0.14	0.54	0.59	0.40
Weed management practices (W)									
W_1: Unweeded control	15.41	16.13	15.77	5.68	5.69	5.69	17.18	18.27	17.72
W_2: Weed free (HW at 20 & 40 DAS)	2.66	2.65	2.66	0.88	0.89	0.89	2.97	3.00	2.99
W_3: Pendimethalin @ 1 kg ha^{-1} (PE)	6.25	6.31	6.28	3.47	3.51	3.49	10.48	10.79	10.64
W_4: Imazethapyr @ 75 g ha^{-1} (POE) at 20 DAS	7.81	7.95	7.88	4.09	4.15	4.12	12.36	12.74	12.55
W_5: Quizalofop ethyl @ 40 g ha^{-1} (POE) at 20 DAS	6.91	6.98	6.94	3.72	3.77	3.75	11.26	11.59	11.43
W_6: W_3 +Imazethapyr @ 75 g ha^{-1} (POE) at 40 DAS	3.83	3.60	3.71	1.41	1.33	1.37	4.27	4.08	4.17
W_7: W_3+Quizalofop ethyl @ 40 g ha^{-1} (POE) at 40 DAS	3.35	3.12	3.23	1.23	1.15	1.19	3.77	3.56	3.66
W_8: Pendimethalin @ 1 kg ha^{-1} (PE) + HW at 40 DAS	2.96	2.74	2.85	0.98	0.91	0.95	3.30	3.10	3.20
S.Em.±	0.28	0.27	0.19	0.10	0.13	0.08	0.31	0.34	0.23
C.D. (P=0.05)	0.80	0.77	0.33	0.29	0.36	0.14	0.89	0.96	0.40
C.V. %	13.68	13.02	13.36	11.49	14.04	12.82	11.39	12.04	11.73
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS

matter accumulation, yield attributes and better weed control efficiency. The lowest grain yield was recorded under unweeded control, which was attributed to better weed growth, and poor yield attributes. The results are in agreement with the findings of Latha and Nadarajan (2009) [4].

All the treatments of plant population differed significantly from each other and independent in their pronounced effect on pods per plant, seeds per pod and test weight. Plant population of 41,666 plants/ha proved its superiority by producing higher pods per plant, seeds per pod and test weight compared to other treatments. While significantly the lowest values of all these parameters were recorded under the higher plant population of 83,333 plants/ha. This was owing to the fact that all the herbicidal treatments under lower plant population produced maximum crop growth, and thereby increased accumulation of photosynthates in reproductive parts, which ultimately reflected in better yield. Pavan *et al.* (2011) and Sarita *et al.* (2012) [2,3] similar results.

Economics

Economic analysis of data [Table-3] showed that plant population of 41,666 plants/ha of pigeon pea was more effective than 55,555 plants/ha and 83,333 plants/ha of pigeon pea in realizing higher net returns and benefit: cost ratio. Net returns and B:C ratio, were maximum with W_2 (Weed free through two hand weedings at 20 & 40 DAS) owing to higher grain yield and comparatively low cost.

The results indicated that higher profitable yield of *rabi* pigeon pea *cv.* GT-102 could be obtained by maintaining the plant population of 41,666 plants/ha and by keeping the crop weed free either by two hand weedings at 20 and 40 days after sowing or by applying Pendimethalin @ 1 kg /ha coupled with hand weeding at 40 days after sowing [5-7].

Conflict of Interest: None declared

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