Short Communication

Bio-efficacy of low volume herbicide molecules on weeds and pigeonpea [*Cajanus cajan* (L.) Millspaugh]

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Pulses are one of the major segments of Indian Agriculture after cereals and oilseeds. Among various pulses grown, pigeonpea [*Cajanus cajan* (L.) Millsp.] ranks second in terms of production in India, while it ranks almost atop in terms of daily consumption of pulses in northern India. In realizing the yield potential of the crop, a sound weed management programme becomes imperative as the weeds start competing fiercely for moisture, nutrients and space right from the sowing of the crop. Many herbicides have been tested and recommended for weed control in pigeonpea crop as pre-sowing or pre-emergence such as alachlor (Pardeshi *et al*., 2008), metolachlor (Nagaraju and Kumar, 2009) and pendimethalin (Singh *et al*., 2010 and Choudhary *et al.,* 2012), pre-plant incorporation and post-emergence in different parts of the country as well as abroad, and the use of herbicides is increasing across the globe day by day owing to increasing labour cost, choice of application of herbicides, quick weed control in crop and non-crop areas. In India, herbicide use has increased more than 30% during the last few decades. Herbicides are chemical in nature, therefore, excessive and repeated use can cause residue problems, phytotoxicity to crop plants, residual effects on susceptible intercrops or succeeding crops, adverse effects on the environment and non-target organisms, and ultimately health hazards to human and animal life. Efficiency and efficacy of herbicides depend largely on its nature, amount, and activity as well as different environmental factors like agro-climatic conditions in which these are used.

The promising herbicides used in pigeonpea and some pulses crops include fluchloralin, pendimethalin, alachlor, metolachlor, paraquat, oxyfluorfen and clomazone (Balyan *et al.,* 1995; Jain *et al.*, 1997 and Yadav *et al.,* 1997). The herbicides currently available for chemical weed control are mostly pre emergence and relatively high in selectivity to crops as most of the herbicides were primarily developed for weed control in economically sound conditions (Gressel, 2002), and intensively precipitate after application that can cause high phytotoxicity to crop, especially in sandy soils (Jursik *et al*., 2011). An overdose of these pesticides causes soil, water, and air contamination and leaves pesticide residue (Tomar, 2010). These herbicides also keep weeds under check only for early part of the crop season (up to 30-40 days after sowing). Moreover, new weed species may emerge at later stages. These herbicides are very costly and have an adverse effect on soil and crop at a higher dose. Therefore, identifying a proper time of application and dose of new generation low volume herbicides; which control the weeds in the later part of the crop season too, and cause least to the environmental hazards; is of the paramount importance. Several investigations have been carried out in different crops with appropriate herbicides which have been found effective at a low dose and also give economic returns to the farmers (Punia *et al.,* 2011). So herbicides use at lower rate/volume, which is eco-friendly along with other mechanical and cultural methods of weed control, gives good control of weeds and is, thereby, helpful in achieving higher crop yields along with complimenting to sustainable environment management. Hence, it is essential to study the efficacy of different new low volume herbicides for their characteristics, doses and time of application and their effects on plant growth and yield of pigeonpea crops which can be used economically as well as environmentally more sound in a sustainable way to have good weed control and achieve higher yields.

A field experiment was conducted during *Kharif* season of 2011 at N. E. Borlaug Crop Research Centre of G. B. Pant University of Agriculture and Technology, Pantnagar. The total rainfall received during the crop season was 1964.2 mm of which the maximum was received during the month of July. The soil of the experimental site was sandy loam in texture as analyzed by Bouyoucus Hydrometer method (Bouyoucus, 1962), medium in organic carbon 0.73%, estimated by Walkley and Black method (Walkley and Black, 1934), medium in available nitrogen 320.8 kg/ha, estimated by micro Kjeldahl method (Subbaiah and Asija, 1956), medium in available phosphorus 19.7 kg ha^{-1} determined by Olsen´s method (Olsen *et al*. 1954), and medium in available potassium 146.2 kg ha^{-1} by Flame Photometry (Jackson, 1973) being slightly alkaline in reaction pH 7.7 determined by glass electrode pH meter method (Jackson, 1973). A total of 10 treatments as T_1 - Weedy check, T_2 - Alachlor 2 kg *a.i.* /ha PE + Paraquat 0.40 kg *a.i.* /ha 42 DAS, T_3 - Pendimethalin 0.75 kg *a.i.* /ha PE followed by 1 HW 50 DAS, T_4 - Imazethapyr 75 g *a.i.* /ha PoE 15 DAS followed by 1 HW 50 DAS, T_5 - Imazethapyr 75 g *a.i.* /ha PoE 10 DAS + Quizalofop ethyl 50 g *a.i.*/ha PoE 15 DAS, T_6 - Tank mix application of Imazethapyr 75 g *a.i.* /ha + Quizalofop ethyl 50 g *a.i.* /ha PoE 15 DAS, T_7 - T_5 followed by 1 HW 50 DAS, T_8 - T_6 followed by 1 HW 50 DAS, T_9 - Pendimethalin 0.75 kg *a.i.* / ha PE + Imazethapyr 60 g *a.i.* /ha PoE 15 DAS and T_{10} - Weed free were assigned in randomized block design with three replications. The pigeonpea var. 'Pant Arhar-3' was sown in 60 cm apart rows with 20 cm plant spacing at 15 kg seed ha^{-1} on June 22, and harvested on December 16 when 90% of the pods turned brown to black in colour. Alachlor and pendimethalin were sprayed next day of sowing and imazethapyr, quizalofop ethyl and paraquat were sprayed on 10, 15 and 42 DAS. While the application of imazethapyr + quizalofop ethyl was done tank mixed, the application of paraquat was done with the help of hood at a spray volume of 500 lit of water ha^{-1}. Spraying was done manually by Knapsack sprayer, following up with a hand weeding after herbicide application as per the treatment. The crop was grown with a standard package of practices for the region. The growth and yield attributes were recorded from five selected plants in each plot. Observations on weeds count (number/m^2) was recorded with help of an iron quadrate 0.5 m x 0.5 m, placed randomly in each plot at 30 DAS interval. The data on weeds were subjected to log (X+1) transformation to normalize their distribution. Weeds samples were cut at ground level, and first dried under sun for a few days and then in a hot air oven at 65°C to 70 °C for 48 to 72 hours for recording the dry matter. Total dry matter was determined by summing up the dry weight of each plant. The data on weed control efficiency were calculated using weed dry weight at 90 DAS which was at the maximum during the weed growth period irrespective of treatments, and calculated by the following formulae (Mani *et al.,* 1973).

$$WCE = \frac{DWC - DWT}{DWC} \times 100$$

Where, WCE = Weed control efficiency, DWT = Dry weight of weeds in treated plot, DWC = Dry weight of weeds in unweeded control plot. The Weed index was calculated by using the formula given by Gill and Kumar, 1969.

$$WI = \frac{YHW - Yt}{YHW} \times 100$$

Where, WI = Weed index, YHW = Average yield of crop in weed free plot, Yt = Average yield of crop in plot under other weed control treatment. The relative efficacy of pre and post emergent herbicides was studied in terms of yield parameters and grain yield. Economics was calculated as per the existing price of inputs and outputs obtained under each treatment at local market. The data for different parameters were statistically analyzed by (Gomez and Gomez, 1984). The mean differences were computed at 5% level of significance.

Weed flora

Weed flora of the experimental site was collected and identified. There were twelve weed species which were identified and classified as grassy weeds, broad-leaved weeds, and sedges. Among the grassy weeds *Echinochloa colona* (L.) Link., *Eleusine indica* (L.), *Cynodon dactylon* (L.), Pers. *Digitaria sanguinalis* (L.) and *Sorghum halepense* (L.) Pers. were dominant species; while in case of broad-leaved weeds *Commelina benghalensis, Celosia argentea* (L.), *Digera arvensis, Molugo pentaphylla* (L.) and *Tianthema monogyna* (L.) were prevalent weeds species; and in case of sedges *Cyperus iria* (L.) and *Cyperus rotundus* (L.) were found predominant weeds species. Naturally, the weeds population as per the temperature requirements grows in the crop hence the grasses; non-grasses weeds were present in the crop. The similar results were also reported by (Sukhadia *et al*., 2000 and Ram *et al*., 2011). Out of twelve weed spp. identified so far only *Echinochloa colona*, *Cynodon dactylon* and *Cyperus rotundus* were most predominant under weedy condition. These data show that these three weeds were the major weeds in the pigeonpea field under Pantnagar conditions. The dominance of these weeds in pigeonpea field has also been reported by (Singh *et al.,* 1998) from Pantnagar.

Total weeds dry matter accumulation per unit area (Table 1) increased consistently with the advancement of crop age up to 90 DAS and decreased, thereafter, in all the treatments. The difference in total weeds dry matter accumulation was significant due to different weed management practices at all the stages of crop growth. The total weeds dry matter production by weeds was significantly higher under weedy check over that of the other weed management practices at all the stages of crop growth. This might be due to the removal of weeds at critical stages of the competition. These findings corroborate the results obtained by (Dhaker *et al.,* 2010). Among the herbicidal treatments T_7 (imazethapyr 75 g *a.i.* ha^{-1} PoE 10 DAS + quizalofop ethyl 50 g *a.i.* ha^{-1} PoE 15 DAS followed by 1 HW 50 DAS) reduced the total weeds dry matter significantly over that of the other treatments except T_8 (tank mix application of imazethapyr 75 g *a.i.* ha^{-1} + quizalofop ethyl 50 g *a.i.* ha^{-1} PoE 15 DAS followed by 1 HW 50 DAS) which remained on a par at earlier stages, i.e. 30 & 90 days. Many researchers have reported lower weed dry weight in pigeonpea and similar crops with the use of herbicides like quizalofop-ethyl (Meena *et al*., 2011) and imazethapyr (Reddy *et al*., 2008, Dhaker *et al*., 2010 and Punia *et al.,* 2011). Imazethapyr is an imidazole compound used as a selective herbicide in a variety of crops. This compound has residual effect extending from a week to several months depending on herbicide dose. This compound controls weeds by reducing the levels of three branched-chain of aliphatic amino acids, isoleucine, leucine, and valine synthesis through inhibition of acetohydroxyacid synthase (ALS), an enzyme common to the biosynthetic pathway for these amino acids. This inhibition causes a disruption in protein synthesis which, in turn, leads to interference in DNA synthesis and cell growth. Imazethapyr is readily absorbed by roots and leaves, translocated by both symplast (phloem) and apoplast (xylem), and accumulated in meristematic tissues. Reports show it is a broad-spectrum herbicide which kills both kinds of grass and broad-leaved weeds very effectively. The total dry matter production was having in weedy check, which increased up to 90 days stage (Table 1). This indicated that crop-weed competition would have been intensified after 90 days stage to reduce weed dry matter of weeds.

The WCE and WI, obviously, remained highest in weed-free and weedy check plots, respectively. As far as the weed management practices are concerned, the treatment T_7 (imazethapyr 75 g *a.i.* ha^{-1} PoE 10 DAS +

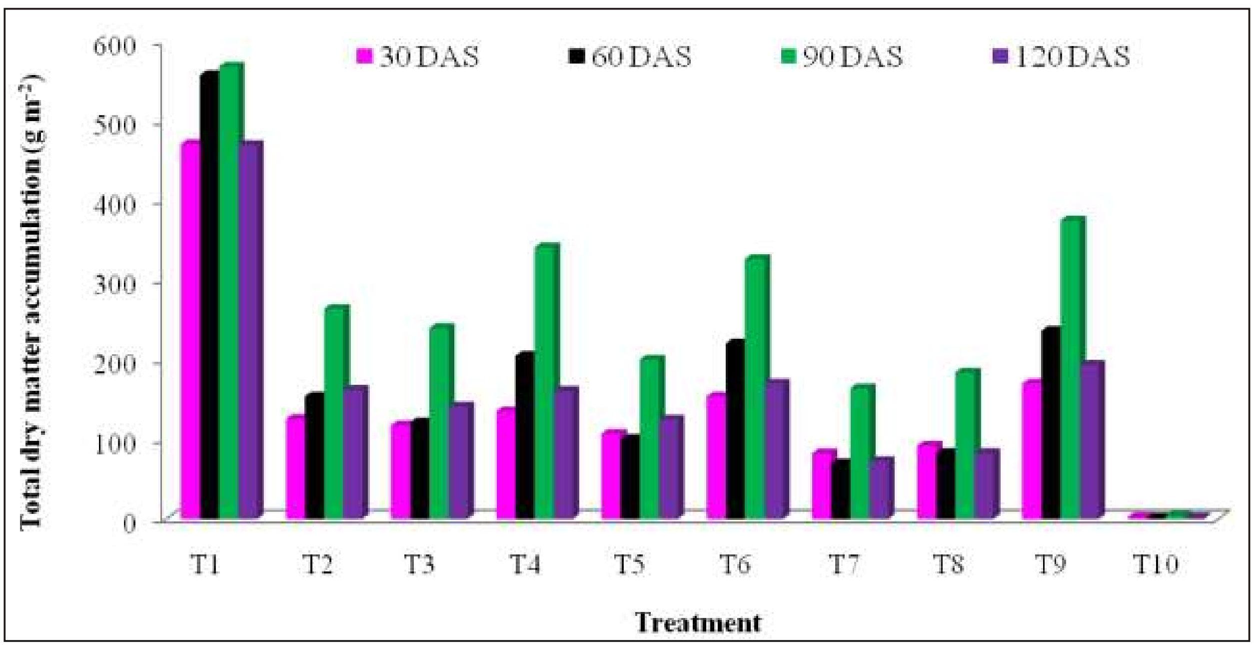

Fig. 1: Effect of weed management practices on total dry matter accumulation of weeds at various stages of crop growth

Table 1: Effect of weed management practices on total dry matter accumulation, weed control efficiency and weed index at various stages of crop growth

Treatment	Total dry matter accumulation of weeds (g m^{-2})				WCE (%)	WI (%)
	30 DAS	60 DAS	90 DAS	120 DAS		
T_1 - Weedy check	6.16 (471.3)	6.33 (557.8)	6.35 (568.7)	6.15 (470.2)	0.00 (0.00)	3.61 (36.47)
T_2 - Alachlor 2 kg a.i. /ha PE + Paraquat 0.40 kg a.i. /ha 42 DAS	4.84 (125.6)	5.04 (154.0)	5.58 (264.0)	5.09 (162.1)	4.00 (53.53)	2.99 (21.00)
T_3 - Pendimethalin 0.75 kg a.i. /ha PE followed by 1 HW 50 DAS	4.71 (117.5)	4.81 (121.3)	5.48 (240.0)	4.96 (141.3)	4.07 (57.75)	2.86 (18.26)
T_4 - Imazethapyr 75 g a.i. /ha PoE 15 DAS followed by 1 HW 50 DAS	4.91 (135.4)	5.33 (204.9)	5.84 (341.3)	5.09 (160.8)	3.71 (39.91)	2.90 (21.27)
T_5 - Imazethapyr 75 g a.i. /ha PoE 10 DAS + Quizalofop ethyl 50 g a.i./ha PoE 15 DAS	4.68 (107.1)	4.62 (100.1)	5.30 (200.0)	4.83 (124.9)	4.19 (64.79)	2.41 (16.33)
T_6 - Tank mix application of Imazethapyr 75 g a.i. /ha + Quizalofop ethyl 50 g a.i. /ha PoE 15 DAS	5.04 (153.8)	5.40 (220.7)	5.79 (326.7)	5.14 (170.2)	3.77 (42.49)	3.03 (21.49)
T_7 - T_5 followed by 1 HW 50 DAS	4.42 (82.3)	4.25 (69.4)	5.11 (164.0)	4.30 (72.7)	4.28 (71.13)	2.21 (9.59)
T_8 - T_6 followed by 1 HW 50 DAS	4.53 (91.9)	4.42 (82.6)	5.23 (184.0)	4.42 (82.5)	4.23 (67.61)	2.44 (11.78)
T_9 - Pendimethalin 0.75 kg a.i. / ha PE + Imazethapyr 60 g a.i. /ha PoE 15 DAS	5.14 (170.3)	5.47 (236.5)	5.93 (375.3)	5.27 (193.7)	3.55 (33.80)	2.29 (20.21)
T_{10} - Weed free	1.13 (2.1)	0.87 (1.4)	1.47 (4.0)	0.98 (1.7)	4.61 (99.29)	0.00 (0.00)
S Em ±	0.05	0.03	0.12	0.04	0.01	0.39
C D (P=0.05)	0.15	0.09	0.35	0.11	0.04	1.17

* Transformed values as log (X+1) ** Original values in parentheses

Table 2: Effect of various weed management practices on yield attributes, pigeonpea yield, net return, and benefits cost ratio.

Treatment	No. of pods/ plant	Length of pod (cm)	No. of seeds/ pod	Seed weight (g/plant)	Stover weight (g/plant)	1000 grain weight	Pigeonpea yield (Kg/ha)		Net return (Kg/ha)	BC ratio
							Grain	Stover		
T_1 - Weedy check	148.3	5.1	3.5	52.5	117.0	74.2	1217	5375	27317	1.22
T_2 - Alachlor 2 kg a.i. /ha PE + Paraquat 0.40 kg a.i. /ha 42 DAS	185.3	6.0	4.1	59.4	149.1	83.5	1508	7002	36386	1.42
T_3 - Pendimethalin 0.75 kg a.i. /ha PE followed by 1 HW 50 DAS	188.9	6.3	4.1	68.1	151.0	85.0	1567	7563	39590	1.54
T_4 - Imazethapyr 75 g a.i. /ha PoE 15 DAS followed by 1 HW 50 DAS	172.7	5.5	4.0	52.9	140.6	80.0	1501	6833	35992	1.38
T_5 - Imazethapyr 75 g a.i. /ha PoE 10 DAS + Quizalofop ethyl 50 g a.i./ha PoE 15 DAS	206.3	6.5	4.2	75.5	180.6	87.7	1600	7897	40560	1.53
T_6 - Tank mix application of Imazethapyr 75 g a.i. /ha + Quizalofop ethyl 50 g a.i. /ha PoE 15 DAS	177.3	5.6	4.0	55.5	148.2	82.5	1508	6835	36094	1.40
T_7 - T_5 followed by 1 HW 50 DAS	239.3	7.1	4.4	80.7	196.0	93.8	1750	8621	45004	1.59
T_8 - T_6 followed by 1 HW 50 DAS	235.1	6.8	4.3	79.6	190.4	90.7	1700	8305	43375	1.57
T_9 - Pendimethalin 0.75 kg a.i. / ha PE + Imazethapyr 60 g a.i. /ha PoE 15 DAS	178.6	5.8	4.1	54.6	146.2	82.8	1508	7017	37399	1.50
T_{10} - Weed free	254.3	7.3	4.5	84.4	204.7	96.0	1933	9185	48859	1.56
S Em ±	6.8	0.5	0.2	2.1	6.7	1.9	95	437	-	-
C D (P=0.05)	20.3	1.4	NS	6.4	19.8	5.5	283	1298	-	-

* Transformed values as log (X+1) ** Original values in parenthesis

quizalofop ethyl 50 g *a.i.* ha^{-1} PoE 15 DAS followed by 1 HW 50 DAS) came up with the highest weed control efficiency and weed index being significantly superior to the other weed management practices except T_8 (tank mix application of imazethapyr 75 g *a.i.* ha^{-1} + quizalofop ethyl 50 g *a.i.* ha^{-1} PoE 15 DAS followed by 1 HW 50 DAS) which did not differ significantly. (Ram *et al.,* 2011) also observed maximum control efficiency of HW in field pea.

Pigeonpea yield

Though the number of pods per plant, pod length, number of grains per pod, seed weight per plant, stover weight per plant, 1000-grain weight, grain yield per hectare and stover yield per hectare were recorded at maximum under weed-free treatments (Table 2), amongst the set of herbicides treatments, the maximum grain and stover yields were recorded with T_7 (imazethapyr 75 g *a.i.* ha^{-1} PoE 10 DAS + quizalofop ethyl 50 g *a.i.* ha^{-1} PoE 15 DAS followed by 1 HW 50 DAS) which was on a par with that of T_8 (tank mix application of imazethapyr 75 g *a.i.* ha^{-1} + quizalofop ethyl 50 g *a.i.* ha^{-1} PoE 15 DAS followed by 1 HW 50 DAS). Higher production of photosynthates might have been transferred to sink which led to more fruiting bodies, *i.e.,* the net result of a number of pods per plant, the length of pod and number of seed per pod and better crop growth as well as conversion efficiency of dry matter to grain. Higher grain yield per plant is, in addition, the outcome of a weed free environment at the initial stage of crop growth till the critical period of the crop-weed competition which facilitated good growth of crop offering least competition for water, nutrients, light and space with the weeds, reflecting ultimately on the grain yield (Ram *et al*. 2012). Furthermore, the apprehension can be made that up to 90 DAS, weeds did not attain much growth and, subsequently, the crop canopy development was sufficient enough to smother the weeds which emerged at the later stages of crop growth. These findings were in agreement with that of (Reddy *et al*., 2007 and Meena *et al*., 2011)

The data on economic studies revealed that the maximum net returns were made under weed-free plot, whereas, the minimum remained under weedy check. Among the herbicidal treatments, T_7 (imazethapyr 75 g *a.i.* ha^{-1} PoE 10 DAS + quizalofop ethyl 50 g *a.i.* ha^{-1} PoE 15 DAS followed by 1 HW on 50 DAS) proved to be more beneficial than all the other treatments. The maximum B: C ratio was obtained under this treatment due to higher yield coupled with low cost of application of herbicides compared to other treatments whereas, the lowest B: C ratio was obtained under the weedy check due to heavy weed competition resulting in lower crop yield. Efficient control of the weeds for a long time during critical crop growth period (due to the integration of herbicides) resulted in higher seed yield coupled with lower cost of cultivation and superior economic indices. In general, the net return and B: C ratio are a function of the total cost of cultivation and the gross returns per hectare. The higher the cost of cultivation, the lower was the net return. These results are in close conformity with those of Punia *et. al. (*2011).

CONCLUSION

In the view of the experimental findings, it may be concluded that a post-emergence application of imazethapyr 75 g *a.i.* ha^{-1} 10 DAS + quizalofop ethyl 50 g *a.i.* ha^{-1} PoE 15 DAS followed by 1 HW 50 DAS may be an alternative to two or more hand weedings for efficient weed control and more grain yield of pigeonpea under *Kharif* planting.

REFERENCES

Balyan, R.S., Singh, S. and Malik, R.K. (1995). Effect of soil and foliage applied herbicides for weed control in mungbean (*V. radiata*). *Haryana Agric. Univ. J. Res*., 25: 35-40.

Bouyoucus, G.J. (1962). Direction for making mechanical analysis of soil by hydrometer method. *Soil Science,* 42: 225-228.

Choudhary, V.K., Kumar, S.P. and Bhagawati, R. (2012). Integrated weed management in blackgram (*Vigna mungo*) under mid hills of Arunachal Pradesh. *Indian J. of Agron.,* 57(4): 382-385.

Dhaker, S.C., Mundra, S.L. and Nepalia, V. (2010). Effect of Weed Management and Sulphur Nutrition on Productivity of Soybean [*Glycine max* (L.) Merrill]. *Indian J. Weed Sci.,* 42(3 & 4): 232-234.

Gill, G.S. and Kumar, V. (1969). Weed index: a new method for reporting weed control traits. *Indian J. of Agron.,* 16(2): 96-98.

Gomez, A. K. and Gomez, A. A. (1984). Statistical Procedure for Agricultural Research. *Int. rice Res. Inst.,* Los Banos Philippines.

Gressel, J.B. (2002). *Molecular Biology of Weed Control.* Taylor & Francis, London.

Jackson, M.L. (1973). *Soil Chemical Analysis*. Prentice Hall pvt. Ltd., New Delhi, India, 498p.

Jain, V.K., Chouhan, Y.S. and Chitnis, V. (1997). Effect of cultural and chemical method of weed management on weed and yield of blackgram *(Phaseolus mungo). Indian J. of Agron.,* 42 (4): 661-664.

Jursik, M., Andr, J; Holec, J. and Soukup, J. (2011). Efficacy and selectivity of post-emergent application of flumioxazin and oxyfluorfen in sunflower. *Plant Soil Environ.,* 57 (11): 532–539.

Mani, V.S., Mola, M.L., Gautam, K.C. and Bhagwn, D. (1973). Weed killing chemicals in potato cultivation. *Indian Farming,* 17(1): 17-18.

Meena, B., Sagarka, B.K. and Pisal, R.R. (2011). Impact of some herbicides and cultural practices on weed and crop parameter in *Kharif* pigeonpea [*Cajanus cajan* (L.) Millsp.]. *Legume Res.*, 34(1): 55-58.

Nagaraju, A.P. and Kumar, H.K.M. (2009). Efficacy of herbicides on weed control in pigeonpea [*Cajanus cajan* (L.) millsp.]. *Mysore J. of Agric. Sci.,* 43: 201-204.

Olsen, S.R., Cole, C.M., Watnode, F.S. and Dean, L.A. (1954). Estimation of available phosphorus of soil by extraction with sodium bicarbonate. *USDA, Cric.:* 939.

Padmaja, B., Reddy, M.M. and Reddy, V.V.D. (2011). Weed control efficiency of pre- and post-emergence herbicides in pigeonpea (*Cajanus cajan* L.). *J. of Food Legumes,* 26(1&2): 44-45.

Pardeshi, S.S., Paturde, J.T., Kagne, S.V., Chavan, P.G., Dhale, S.A and Raut, V.S. (2008). Effect of weed management practices on weed growth and grain yield of maize + pigeonpea intercropping system. *J. of Soils and Crops,* 18: 454-457.

Punia, S.S., Singh, S. and Yadav, D. (2011). Bioefficacy of Imazethapyr and Chlorimuron-ethyl in Clusterbean and their Residual Effect on Succeeding Rabi Crops. *Indian J. Weed Sci*., 43(1 & 2): 48-53.

Ram, B., Punia S.S., Meena, D.S. and Tetarwal, J.P. (2011). Bio-efficacy of posts emergence herbicides to manage weeds in field pea. *J. of Food Legumes,* 24: 254-257.

Ram, B., Punia S.S., Meena D.S. and Tetarwal, J.P. (2012). Efficacy of post-emergence herbicides on weed control and seed yield of rajmash (*Phaseolus vulgaris* L.). *J. of Food Legumes,* 25: 306-309.

Reddy, M.M., Padmaja B. and Rao L.J. (2008). The response of *Rabi* pigeonpea to irrigation scheduling and weed management in alfisols. *J. of Food Legumes,* 21: 237-239.

Reddy, M.M., Madhavilatha A. and Rao L.J. (2007). Integrated weed management in pigeonpea (*Cajanus cajan*) - soybean (*Glycine max*) intercropping system in Vertisol under rainfed conditions. *Indian J. of Agric. Sci.,*77: 177-178.

Singh, G., Aggarwal, N. and Ram, H. (2010). Effect of row spacing and weed management practices on weeds, growth and yield of pigeonpea [*Cajanus cajan* (L.) millsp.]. *Indian J. of Weed Sci.,* 42:241-243.

Singh, V.K., Singh, N.P., Sharma B.B. and Sahu, J.P. (1998). Effect of planting methods and weed-control practice on weed management and productivity of pigeonpea (*Cajanus cajan*) in foothills region. *Indian J. of Agron.,* 4(3): 685-688.

Subbaiah, B.V. and Asija, G.L. (1956). A rapid procedure for the determination of available nitrogen in the soils. *Curr. Sci.* , 25: 259-260.

Sukhadia, N.M., Ramani, B.B., Modhwadia, M.M. and Asodaria, K.B. (2000). Integrated weed management in pigeonpea (*Cajanus cajan* L. Millsp.). *Gujarat Agric. Univ. Res. J.,* 25(2): 1-4.

Tomar, R.A.S. (2010). *Encyclopedia of Agricultural Chemistry*. New Delhi: Anmol Publications PVT. LTD., 1: 1-20.

Walkey, A. and Black, T.A. (1934). Examination of the Deglareff methods for determination of soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science,* 37: 29-38.

Yadav, R.P., Yadav, K.S. and Shrivastava, V.K. (1997). Integrated weed management in blackgram (*Phaseolus mungo*). *Indian J. Agron.*, 42 (1): 124-126.

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