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Short Communication

Weed biomass and yield of greengram (*Vigna radiata*) as affected by sequential application of herbicides in Indo-Gangetic Plains

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Greengram [*Vigna radiata* L. Wilczek] is one of the important pulse crop of India. The average productivity of greengram is only 0.4 tonne/ha (DAC 2013) which is quite low against its potential yield. It is usually accompanied by luxuriant weed growth during the rainy (*kharif*) season owing to abundant rainfall received during monsoons period. It results in serious yield losses in greengram. The crop is not a very good competitor against weeds (Kumar *et al.* 2005), particularly during early growth period and therefore, weed management is very crucial for proper crop growth. Depending on the variety, season, soil type, nature, density and duration of weed competition, the extent of yield reduction due to weeds vary from 30 to 85% in greengram (Malik *et al*. 2000, Punia *et al*. 2004). Greengram is more sensitive to weed competition in the first 4–5 weeks after emergence due to slow growth. Currently, only pre-plant/ pre-emergence herbicides are available which are recommended to control weeds in greengram. Sometimes, owing to early rains soon after sowing it is impossible to spray pre-emergence herbicides. Further, many times weeds emerge at a later stage, which need to be controlled with post-emergence or sequential application of herbicides. So, sequential application of herbicides could be an effective tool to manage weeds at right time. Therefore, the present investigation was undertaken to evaluate the performance of sequential application of herbicides for weed management in greengram under Indo-Gangetic Plains.

The experiment was conducted at the ICAR-Indian Agricultural Research Institute, New Delhi (28° 352 N, 77° 122 E, 228.6 m above mean sea level) during *kharif* 2013. The soil was sandy loam with pH 7.6, organic carbon 0.38%, available N 259 kg/ha, available P 9.2 kg/ha and available K 260 kg/ha. The total rainfall of 469.6 mm was received in 27 rainy days during the crop growing season. Two irrigations were given to the crop one at pre flowering and another one at pod formation stage. This field experiment consisting of twelve weed control treatments including pendimethalin @ 1 kg/ha PE, pendimethalin @ 1 kg/ha PE + 1 HW at 30 DAS, pendimethalin @ 0.75 kg/ha PE + imazethapyr @ 50g/ha at 30 DAS, pendimethalin @ 0.75 kg/ha PE + imazethapyr @ 75g/ha at 30 DAS, imazethapyr @ 50 g/ha at 20 DAS, imazethapyr @ 75 g/ha at 20 DAS, pendimethalin @ 0.75 kg/ha PE + quizalofop @ 50g/ha at 30 DAS, pendimethalin @ 0.75 kg/ha PE + quizalofop @ 75g/ha at 30 DAS, quizalofop @ 50 g/ha at 20 DAS, quizalofop @ 75 g/ha at 20 DAS, weed free and a weedy check was laid out in randomised complete block design with three replication. A uniform recommended dose of 30 kg N/ha, 60 kg P_2O_5/ha and 40 kg K_2O/ha was applied through urea, DAP and MOP respectively. Full dose of N, P_2O_5 and K_2O were applied at the time of sowing as basal. Pusa Ratna cultivar of greengram was sown in rows 30 cm apart using a seed rate of 15 kg/ha by *kera* method. The seeding depth was kept at 3-4 cm. Sowing was done on 31 July 2013. Herbicides were applied with the help of a manually operated knapsack sprayer fitted with flat-fan nozzle at a spray volume of 500 l/ha. The crop was sprayed with dimethoate (Rogor) to control insect-pests particularly white flies (*Bemisia tabaci*), the vector for yellow mosaic virus. In all, 3 sprays were done as and when early symptoms of white flies were noticed. Data on weeds were recorded at 50 days after sowing (DAS) in each plot in two quadrates, each measuring 50 cm × 50 cm. Weeds were counted species-wise and removed for recording their dry weights. Weed samples were sun dried before oven drying at 70°C until constant weight was attained. The weed control efficiency (WCE) was calculated by using the following formula (Patel *et al.* 1983).

$$\text{Weed control efficiency (WCE)} = \frac{WD_C - WD_T}{WD_C} \times 100$$

where, WD_C , weed density (number/m^2) in control plot; WD_T , weed density (number/m^2) in treated plot.

Weed index was worked out using following expression (Gill and Vijayakumar 1969).

$$\text{Weed Index} = \frac{Y_{WF} - Y_T}{Y_{WF}} \times 100$$

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where, X , crop yield from weed free plot; Y , crop yield from treated plot.

All the growth attributes, viz. plant height, number of primary branches and leaf area index were recorded at 50 DAS. The data on yield attributes, viz. number of pods/plant, pod length and number of seeds/pod were recorded at crop maturity from 5 plants marked in second row of each plot. The pods were picked three times before actually harvesting the crop on 15 October 2013. The harvested pods of these three pickings were mixed treatment wise and then sun dried for 3 days. These dried pods were manually-threshed separately from each experimental plot. Threshed seeds were cleaned and weighted to record the seed yield/plot. The data on seed yield was converted into tonnes/ha and reported at 14% seed moisture. The treatments like weed free and weedy check lays the egg for large variation. Weed free usually corresponds to zero or lower value and weedy check maximum or highest values of parameter studied. When taken together and analysed with other treatments, they themselves are responsible for higher inherent treatment variance as well as higher replication and block variance. Therefore, to stabilise the variance data on weeds were subjected to square root transformation prior to statistical analysis to normalise their distribution. The analysis of variance of data under randomized block design was carried out using SAS 9.2 software and treatments were compared by computing F-test. LSD values at $P= 0.05$ were used to determine the significance of differences between treatment means.

The major weed flora in the experimental field included *Cyperus rotundus* L., *Digitaria sanguinalis* (L.) Scop, *Dactyloctenium aegyptium* (L.) P. Beauv., *Trianthema portulacastrum* L. and *Digera arvensis* Forsk. All the weed control treatments proved effective in minimizing the density and dry weight of weeds over weedy check (Table 1). Sequential application of herbicides was more effective than their one time application either as PE or POE. This was mainly due to weed free conditions provided by the sequential application of herbicides for proper growth and development of greengram. However, in case of one time application of herbicides, either as PE or POE both the greengram crop and weeds competed with each other for resources during latter part of the crop growth. Among the weed control treatments, pendimethalin @ 1 kg/ha PE + 1 HW at 30 DAS was found most effective in reducing the weed population and dry weight, and was closely followed by pendimethalin at 0.75 kg/ha PE + imazethapyr @ 75 g/ha at 30 DAS. Raman and Krishnamoorthy (2005) have also reported that pre-emergence application of pendimethalin at 1.0 kg/ha + 1 HW at 30 DAS was most effective method of weed control. The lowest reduction in weed growth was observed with pendimethalin @ 1 kg/ha at 30 DAS. It suggests that application of pendimethalin alone without combining it with HW or other herbicides in sequence proved less effective in controlling the weeds. The highest weed control efficiency (WCE) of 75.2% was recorded with application of pendimethalin @ 1 kg/ha PE + 1 HW at 30 DAS followed by pendimethalin @ 0.75 kg/ha PE + imazethapyr @ 75 g/ha (68.7%) at 30 DAS. The initial weed growth was ceased due to effect of pre-emergence herbicide and forth coming grassy weed flushes were then suppressed by the POE application of imazethapyr at 30 DAS, resulting in higher WCE. The lowest WCE was recorded with pendimethalin @ 1 kg/ha PE and quizalofop @ 50 g/ha and @ 75 g/ha at 20 DAS. Similar results of higher WCE of imazethapyr were also reported by Dubey *et al.* (2012). Efficient control of weeds by sequential application of herbicides over their one time application either as PE or POE led to better values of growth and yield attributes in greengram. Pendimethalin @ 1 kg/ha PE + 1 HW at 30 DAS resulted in higher plant height, number of primary branches/plant, leaf area index, number of pods/plant, pod length and number of seeds/pod over rest of the weed control treatments (Table 2). Although pendimethalin @ 0.75 kg/ha PE + imazethapyr @ 75g/ha at 30 DAS was found at par to the preceding treatment. This may have happened due to better control of weeds, which reduced the intensity of crop-weed competition. The lowest weed index (8.3%), total weed density (7.1 no./m^2) and total weed dry weight (6.0 g/m^2) was recorded with pendimethalin @ 1 kg/ha PE + 1 HW at 30 DAS which was found at par with pendimethalin @ 0.75 kg/ha PE + imazethapyr @ 75g/ha at 30 DAS. The lower weed density and dry weight was mainly due to inhibition of germination of weeds owing to paralysis of various vital metabolic processes, like cell division and protein synthesis which led to drying of susceptible weed species (Ramsak 2001). The highest grain yield (1.10 tonnes/ha) was recorded with pendimethalin @ 1 kg/ha PE + 1 HW at 30 DAS, and was comparable with pendimethalin @ 0.75 kg/ha PE + imazethapyr @ 75g/ha at 30 DAS. Pendimethalin @ 1 kg/ha PE + 1 HW at 30 DAS recorded 58% higher seed yield as compared to weedy check and 27.3 to 35.5% higher seed yield compared to one time herbicide application treatments. Raman and Krishnamoorthy (2005) also reported that pre-emergence application of Pendimethalin at 1.0 kg/ha + 1 HW at 20–30 DAS was most effective method in controlling weeds and resulted in the highest seed yield of greengram. Malik *et al.* (2005) also reported that application of Pendimethalin at 1.5 kg/ha + 1 HW at 30 DAS resulted in higher greengram seed yield than Pendimethalin at 1.5 kg/ha or 1 HW at 30 DAS alone. The higher seed yield in treatments involving sequential application of herbicides, pre-emergence application of herbicides + 1 HW at 30 DAS could be owing to better weed control which ultimately increased the values of yield attributes. Chhodavadia *et al*. (2013) also reported the similar kind of findings.

We conclude that sequential application of pendimethalin @ 0.75 kg/ha PE + imazethapyr @ 75g/ha @ 30 DAS (POE) was as effective as pre-emergence application of pendimethalin @ 1kg/ha + 1 HW at 30 DAS in controlling weeds and increasing the seed productivity of greengram. Thus the sequential application of above herbicides combination could be an efficient alternative to control

Table 1 Effect of weed control treatments on species wise weed growth at 50 days after sowing

Treatment	*C. rotundus*		*D. aegyptium*		*D. sanguinalis*		*T. portulacastrum*		*D. arvensis* Weed		
	Density (no./m^2)	Dry weight (g/m^2)	Density (no./m^2)	Dry weight (g/m^2)	Density (no./m^2)	Dry weight (g/m^2)	Density (no./m^2)	Dry weight (g/m^2)	Density (no./m^2)	Dry weight (g/m^2)	control efficiency (%)
Pendimethalin @ 1 kg/ha PE	5.87 (34.0)	5.03 (24.8)	3.91 (14.8)	5.03 (24.8)	4.71 (21.7)	5.16 (26.1)	5.12 (25.7)	5.52 (30.0)	4.95 (24.0)	5.08 (25.3)	33.68
Pendimethalin @ 1 kg/ha PE + 1 HW at 30 DAS	4.30 (18.0)	2.74 (7.0)	2.66 (6.6)	3.02 (8.6)	3.08 (9.0)	3.05 (8.8)	3.08 (9.0)	4.34 (18.3)	2.70 (6.8)	3.24 (10.0)	75.21
Pendimethalin @ 0.75 kg/ha PE + imazethapyr @ 50g/ha at 30 DAS	4.74 (22.0)	3.33 (10.6)	3.24 (10.0)	3.51 (11.8)	3.62 (12.6)	3.55 (12.1)	3.48 (11.6)	4.64 (21.0)	3.30 (10.4)	3.61 (12.5)	68.59
Pendimethalin @ 0.75 kg/ha PE + imazethapyr @ 75g/ha at 30 DAS	4.68 (21.4)	3.24 (10.0)	3.08 (9.0)	3.52 (11.9)	3.35 (10.7)	3.42 (11.2)	3.51 (11.8)	4.54 (20.1)	3.16 (9.5)	3.63 (12.7)	68.69
Imazethapyr @ 50 g/ha at 20 DAS	5.52 (30.0)	4.53 (20.0)	3.75 (13.6)	4.37 (18.6)	4.02 (15.7)	4.38 (18.7)	3.79 (13.9)	5.05 (25.0)	3.45 (11.4)	3.96 (15.2)	57.55
Imazethapyr @ 75 g/ha at 20 DAS	5.35 (28.1)	4.45 (19.3)	3.66 (12.9)	4.30 (18.0)	3.81 (14.0)	4.37 (18.6)	3.74 (13.5)	4.85 (23.0)	3.26 (10.1)	3.94 (15.0)	60.56
Pendimethalin @ 0.75 kg/ha PE + quizalofop @ 50g/ha at 30 DAS	4.24 (17.5)	3.27 (10.2)	3.11 (9.2)	3.42 (11.2)	3.41 (11.1)	3.54 (12.0)	5.24 (27.0)	5.70 (32.0)	4.38 (18.7)	5.05 (25.0)	58.10
Pendimethalin @ 0.75 kg/ha PE + quizalofop @ 75g/ha at 30 DAS	4.18 (17.0)	3.30 (10.4)	3.08 (9.0)	3.46 (11.5)	3.10 (9.1)	3.49 (11.7)	5.05 (25.0)	5.57 (30.5)	4.10 (16.3)	4.85 (23.0)	61.66
Quizalofop @ 50 g/ha at 20 DAS	4.90 (23.5)	3.85 (14.3)	3.74 (13.5)	3.70 (13.2)	3.85 (14.3)	3.94 (15.0)	6.36 (40.0)	5.83 (33.5)	6.31 (39.3)	5.43 (29.0)	34.47
Quizalofop @ 75 g/ha at 20 DAS	4.85 (23.0)	3.81 (14.0)	3.69 (13.1)	3.67 (13.0)	3.67 (13.0)	3.86 (14.4)	6.44 (41.0)	5.72 (32.2)	6.15 (37.3)	5.52 (30.0)	36.07
Weed free	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	100
Weedy check	6.94 (47.7)	6.20 (38.0)	4.60 (20.7)	5.97 (35.2)	6.02 (35.8)	6.73 (44.8)	6.75 (45.0)	7.67 (58.3)	6.53 (42.1)	7.78 (60.0)	00
SEm±	0.12	0.09	0.16	0.21	0.09	0.19	0.09	0.02	0.21	0.05	1.8
LSD (P=0.05)	0.35	0.27	0.43	0.62	0.27	0.56	0.27	0.06	0.61	0.15	3.5

PE, Pre-emergence; DAS , Days after sowing. Data were subjected to $(\sqrt{x+0.5})$ transformation before statistical analysis. Figures in parentheses are the original values.

Table 2 Effect of weed control treatments on combined growth of all weeds, and yield and its attributes in greengram

Treatment	Total weed density (no/m^2)	Total weed dry weight (g/m^2)	Plant height (cm)	No. of primary branches / plant	Leaf area index	Dry weight/ plant (g)	No. of pods/ plant	Pod length (cm)	No. of seeds/pod	Seed yield (t/ha)	Weed index (%)
Pendimethalin @ 1 kg/ha pre-emergence (PE)	10.99 (120.2)	11.47 (131.0)	46.20	3.52	3.09	9.84	12.50	9.0	8.30	0.79	34.17
Pendimethalin @ 1 kg/ha PE + 1 HW at 30 DAS	7.06 (49.4)	6.02 (35.8)	54.20	4.75	4.28	12.24	19.33	11.17	10.33	1.10	8.33
Pendimethalin @ 0.75 kg/ha PE + imazethapyr @ 50g/ha at 30 DAS	7.94 (62.6)	8.40 (70.0)	52.73	4.62	3.89	11.81	17.00	9.62	8.79	0.99	17.50
Pendimethalin @ 0.75 kg/ha PE + imazethapyr @ 75g/ha at 30 DAS	7.93 (62.4)	8.03 (64.0)	53.79	4.58	4.0	12.12	16.60	9.67	8.83	1.02	15.00
Imazethapyr @ 50 g/ha at 20 DAS	9.22 (84.6)	10.10 (101.6)	48.62	3.66	3.50	10.55	13.18	8.41	8.00	0.77	35.83
Imazethapyr @ 75 g/ha at 20 DAS	8.89 (78.6)	9.67 (93.1)	48.63	3.86	3.55	10.13	13.29	8.49	8.18	0.80	33.33
Pendimethalin @ 0.75 kg/ha PE + quizalofop @ 50g/ha at 30 DAS	9.17 (83.5)	8.73 (75.7)	50.12	4.40	3.60	10.99	15.60	9.00	8.40	0.89	25.83
Pendimethalin @ 0.75 kg/ha PE + quizalofop @ 75g/ha at 30 DAS	8.77 (76.4)	8.22 (67.1)	50.44	4.42	3.67	11.12	15.83	8.95	8.35	0.93	22.50
Quizalofop @ 50 g/ha at 20 DAS	11.45 (130.6)	10.31 (105.7)	43.00	3.33	2.93	9.00	12.87	7.50	7.85	0.71	40.83
Quizalofop @ 75 g/ha at 20 DAS	11.31(127.4)	10.03 (100.1)	44.94	3.22	2.90	9.92	12.80	7.80	7.90	0.75	37.50
Weed free	0.71 (00)	0.71 (00)	58.45	5.00	4.51	12.4	22.00	12.00	10.50	1.20	0.00
Weedy check	14.14 (199.3)	16.80 (281.8)	39.33	2.90	2.38	8.72	9.00	5.64	5.80	0.46	61.67
SEm±	0.05	0.02	1.09	0.09	0.15	0.30	1.08	0.61	0.67	0.04	2.29
LSD (P=0.05)	0.15	0.06	3.20	0.27	0.44	0.88	3.15	1.81	2.01	0.11	6.8

PE, Pre-emergence; DAS , Days after sowing. Data were subjected to transformation before statistical analysis. Figures in parentheses are the original values.

weeds in greengram, especially when HW is not feasible at later stages of crop growth.

SUMMARY

A field experiment was conducted during the rainy season of 2013 at the research farm of the ICAR-Indian Agricultural Research Institute, New Delhi to evaluate the performance of sequential application of herbicides for weed management in greengram [*Vigna radiata* (L.) Wilczek]. The experiment was laid out in randomized complete block design with 3 replications. The weed control treatments (12) were: pendimethalin @ 1 kg/ha pre-emergence (PE), pendimethalin @ 1 kg/ha PE + 1 HW at 30 days after sowing (DAS), pendimethalin @ 0.75 kg/ha PE + imazethapyr @ 50g/ha post-emergence (POE) at 30 DAS, pendimethalin @ 0.75 kg/ha PE + imazethapyr @ 75g/ha POE at 30 DAS, imazethapyr @ 50 g/ha POE at 20 DAS, imazethapyr @ 75 g/ha POE at 20 DAS, pendimethalin @ 0.75 kg/ha PE + quizalofop @ 50g/ha POE at 30 DAS, pendimethalin @ 0.75 kg/ha PE + quizalofop @ 75g/ha POE at 30 DAS, quizalofop @ 50 g/ha POE at 20 DAS, quizalofop @ 75 g/ha POE at 20 DAS, weed free and weedy check. Sequential application of herbicides was more effective than their one time application either PE or POE in suppressing weed growth in terms of density and dry weight. Pendimethalin @ 1 kg/ha PE + 1 HW at 30 DAS resulted in highest seed yield (1.10 t/ha), weed control efficiency (75.21%), lowest weed dry weight (6.02 g/m^2), weed density (7.06 no/m^2) and weed index (8.33%). However, this treatment did not differ significantly from pendimethalin @ 0.75 kg/ha PE + imazethapyr @ 75g/ha POE at 30 DAS. Therefore, sequential application of herbicides can be an effective alternative to manage weeds in greengram.

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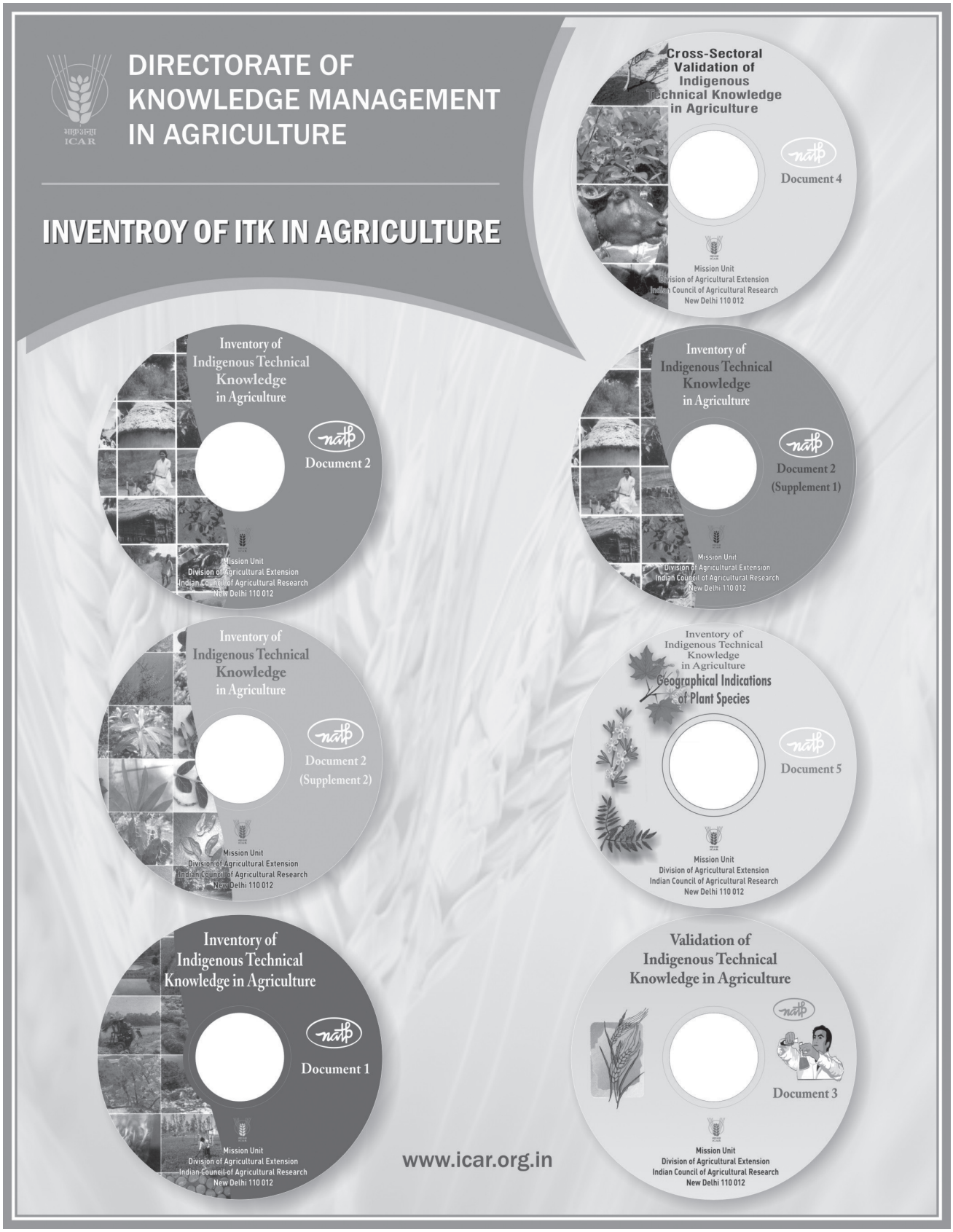
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