Indian Journal of Agronomy **67** (3): 320–323 (September 2022)

Research Communication

Effect of tillage and herbicides on growth, weed control and energetics of chickpea (*Cicer arietinum*) grown in sequence with sorghum (*Sorghum bicolor*)

TONY MANOJ KUMAR N.[1] AND A.R. SHARMA[2]

Rani Lakshmi Bai Central Agricultural University, Jhansi, Uttar Pradesh 284 003

Received: August 2021; Revised accepted: July 2022

ABSTRACT

An experiment was conducted during 2019–20 on sandy clay-loam soil at the Rani Lakshmi Bai Central Agricultural University, Jhansi, Uttar Pradesh, to evaluate the effect of tillage and herbicides on growth, weed control, economics and energetics of chickpea (*Cicer arietinum* L.). Treatments included 3 tillage, viz. zero-tillage (ZT), ZT along with sorghum [*Sorghum bicolor* (L.) Moench] residue (ZT + R) and conventional tillage (CT), in main plot; and 4 weed-management practices, viz. pendimethalin alone, pendimethalin followed by (*fb*) clodinafop-propargyl + Na-acifluorfen, pendimethalin *fb* hand-weeding and unweeded check, in subplots. Chickpea growth and development was higher under ZT + R, which led to higher grain yield, economics, and energetics. Net returns under ZT + R were 13.5% more than ZT but 36.7% more than CT. Chickpea grown under ZT and ZT + R with pendimethalin *fb* clodinafop + Na-acifluorfen was 32.7–43.5% more energy-efficient than the same treatment under CT. This study indicated that chickpea grown after sorghum under ZT + R with pendimethalin *fb* clodinafop + Na-acifluorfen was economical and energy-efficient apart from providing higher grain yield in Bundelkhand region.

Key words: Clodinafop + Na-acifluorfen, Energy, Pendimethalin, Sorghum residue, Weed-control efficiency, Zero tillage

Chickpea (*Cicer arietinum* L.) is grown in the winter season in sequence with different crops like rice, maize, soybean, sorghum and pearlmillet in the states of Madhya Pradesh, Maharashtra, Rajasthan, Andhra Pradesh, Tamil Nadu, Karnataka, Uttar Pradesh and Gujarat (Adarsh *et al*., 2019). Being a relatively low-water requiring crop, sorghum [*Sorghum bicolor* (L.) Moench]–chickpea system is followed in some areas of Madhya Pradesh and Maharashtra. Productivity of chickpea in India is quite low (1,073 kg/ha) considering its potential (up to 3 t/ha) with better soil and crop-management. Efficiency of various inputs is influenced by crop-management practices like tillage and weed management. Tillage which involves energy influences the emergence of weeds and also the efficiency of added fertilizer, water and herbicides. Similarly, weed management is critical for improving the efficiency of these external inputs. Ultimately, it is the economic efficiency which matters for adoption of the technology by the end-users. Various indices are often used for working out the efficiency of tillage and weed control (Poonia and Pithia, 2013; Kumar *et al*., 2017). Hence a study was carried out to evaluate growth, weed control and energy efficiency as influenced by these practices in chickpea grown after sorghum.

An experiment was conducted on sandy clay-loam soil at the research farm of the Rani Lakshmi Bai Central Agricultural Univeristy, Jhansi, Uttar Pradesh during 2019–20 to evaluate the effect of tillage and weed-management practices on growth, weed control, economics and energetics of chickpea grown after sorghum. Twelve treatment combinations comprising 3 tillage practices in main plot, viz. zero tillage (ZT), ZT with sorghum residue (ZT + R) and conventional tillage (CT), and 4 weed-management practices in subplot, viz. pendimethalin 1 kg/ha as pre-emergence, pendimethalin pre-em followed by (*fb*) clodinafop-propargyl + Na-acifluorfen 122.5 g/ha at 30 days after sowing (DAS), pendimethalin pre-em *fb* hand-weeding (HW) at 30 DAS and unweeded check, were laid out in a split-plot design with 3 replications. Sowing of chickpea cv. RVG 202 was done with happy seeder, with basal application of 100 kg diammonium phosphate/ha. In the previous rainy (*kharif*) season, sorghum was grown as

Based on a part of the M.Sc. thesis submitted by the first author to the Rani Lakshmi Bai Central Agricultural University, Jhansi, Uttar Pradesh in 2020 (unpublished)

[2]Corresponding author's Email: tonymanoj98@gmail.com

[1]Ph.D. Student (Agronomy), Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand 263 145; [2]Director Research, Rani Lakshmi Bai Central Agricultural University, Jhansi, Uttar Pradesh 284 003

a uniform crop and the residue @ 5 t/ha was retained on the soil surface in the respective treatments of the experiment. Glyphosate was applied at 1.0 kg/ha before sowing chickpea in the ZT plots. One irrigation was given to chickpea in mid-January.

Growth and efficiency indices like crop-growth rate (CGR), relative growth rate (RGR), weed-control efficiency (WCE), herbicidal efficiency index (HEI) (Das *et al*., 2016), economics and energetics (Chamsing *et al*., 2006) as affected by tillage and weed-control practices were worked out following standard procedures.

Crop-growth rate (CGR) was quite slow at 0–30 DAS, but increased and remained almost similar at 31–60 DAS and 61–90 DAS (Table 1). On the other hand, the RGR showed a rapid decline from 31–60 DAS to 61–90 DAS. Application of clodinafop + Na-acifluorfen had a depressing effect on CGR and RGR from 31–60 DAS, but the crop recovered and showed the highest value of both these indices at 61–90 DAS. This showed that, post-emergence application of clodinafop + Na-acifluorfen could be considered as a choice to check weed growth as well as excessive vegetative growth during the grand growth period, and promote CGR and RGR during the reproductive phase of chickpea.

Grain yield of chickpea increased from 0.84 t/ha under CT – unweeded control by more than 2-fold to a maximum of 2.02 t/ha under ZT + R with application of pendimethalin *fb* clodinafop + Na-acifluorfen (Table 2). This indicated that, the loss in yield due to unchecked weed control was up to 58.4%, and the yield could be increased by 14.5% through manipulation of tillage and weed management. The ZT was highly beneficial, more so along with sorghum residue compared with CT under all weed-control practices. Being a bold-seeded crop, chickpea did not require fine seed-bed, while reside retention helped in moderating hydro-thermal regime (Acharya *et al*., 2018) as well as weed control. Sequential herbicidal application was significantly better than herbicide + HW despite some adverse effect of clodinafop + Na-acifluorfen applied as post-emergence. This could be considered as an important observation for season-long weed control and an alternative to manual weeding.

Pre-emergence application of pendimethalin had a pronounced effect on weed density. The highest weed-control efficiency (WCE) was observed under ZT + R with pendimethalin *fb* clodinafop + Na-acifluorfen (92.7%) (Table 2). Application of pendimethalin *fb* clodinafop + Na-acifluorfen enabled effective control of diverse weed flora and resulted in higher WCE at 60 DAS. Further, presence of sorghum residue on the soil surface helped in reduced exposure of weed seeds to the sunlight leading to reduced germination and emergence (Chauhan *et al*., 2012).

Pre-emergence application of pendimethalin *fb* clodinafop + Na-acifluorfen provided efficient weed control and significantly enhanced the grain yield over the other treatment combinations. Accordingly, the herbicidal efficiency index (HEI), which is the ratio of per cent increase in grain yield to per cent weed dry-matter, was more in treatments with higher yield and lower weed dry weight. The highest HEI was under CT with pendimethalin *fb* clodinafop + Na-acifluorfen (5.96), followed by that under ZT + R (5.16) and ZT (4.10). However, the performance of pendimethalin *fb* hand-weeding (HW) was relatively better

Table 1. Effect of tillage and weed-management practices on growth indices of chickpea

Treatment	Crop-growth rate (g/m^2/day)			Relative growth rate (mg/g/day)	
	0–30 DAS	31–60 DAS	61–90 DAS	31–60 DAS	61–90 DAS
Tillage					
ZT	0.80	5.19	5.31	67.0	21.2
ZT + R	0.81	5.25	5.47	67.2	21.6
CT	0.88	4.86	4.99	62.4	20.9
SEm±	0.02	0.03	0.05	0.8	0.1
CD (P=0.05)	NS	0.11	0.18	3.1	0.4
Weed-management					
Pendimethalin	0.80	5.57	5.01	69.2	19.2
Pendimethalin *fb* clodinafop + Na-acifluorfen	0.85	4.73	6.14	62.9	24.9
Pendimethalin *fb* HW	0.84	5.69	5.08	68.6	19.4
Unweeded control	0.83	4.41	4.76	61.4	21.5
SEm±	0.02	0.02	0.04	0.7	0.1
CD (P=0.05)	NS	0.06	0.11	2.2	0.2

ZT, zero tillage; R, residue; CT, conventional tillage; *fb*, followed by; HW, hand-weeding; DAS, days after sowing; NS, non-significant

Table 2. Grain yield and efficiency indices in chickpea as influenced by tillage and weed control practices

Treatment	Grain yield (t/ha)	Weed-control efficiency at 60 DAS (%)	Herbicidal efficiency index	Economics: Total cost of cultivation (×10³ ₹/ha)	Economics: Gross returns (×10³ ₹/ha)	Economics: Benefit: cost ratio	Energy: Total energy input (×10³ ₹/ha)	Energy: Total energy output (×10³ MJ/ha)	Energy: Energy-use efficiency (output/ input)	Energy: Energy productivity (kg yield/MJ)
ZT										
Pendimethalin	1.48	76.3	1.25	26.3	73.8	2.81	8.11	44.6	5.50	0.41
Pendimethalin *fb* clodinafop + Na-acifluorfen	1.83	89.4	4.10	27.7	91.4	3.30	8.15	52.5	6.43	0.48
Pendimethalin *fb* HW	1.71	88.2	3.34	29.6	85.1	2.87	8.26	48.5	5.86	0.43
Unweeded control	1.04	–	–	23.8	51.9	2.18	7.81	30.7	3.93	0.29
ZT + R										
Pendimethalin	1.65	73.0	0.89	28.8	82.8	2.87	8.11	51.7	6.38	0.47
Pendimethalin *fb* clodinafop +Na-acifluorfen	2.02	92.7	5.16	30.2	101.3	3.36	8.15	62.5	7.67	0.57
Pendimethalin *fb* HW	1.91	87.3	2.66	32.1	95.3	2.97	8.26	56.9	6.89	0.51
Unweeded control	1.26	–	–	26.3	63.3	2.41	7.81	42.2	5.40	0.40
CT										
Pendimethalin	1.37	76.6	1.65	31.3	68.0	2.17	11.7	37.2	3.24	0.24
Pendimethalin *fb* clodinafop + Na-acifluorfen	1.71	91.5	5.96	32.7	85.6	2.62	11.8	51.0	4.33	0.32
Pendimethalin *fb* HW	1.50	87.1	3.40	34.6	74.6	2.16	11.9	43.0	3.65	0.27
Unweeded control	0.84	–	–	28.8	41.8	1.45	11.4	23.6	2.06	0.15
SEm±	0.02	–	–	–	–	–	–	–	–	–
CD (P=0.05)	0.06	–	–	–	–	–	–	–	–	–

ZT, zero tillage; R, residue; CT, conventional tillage; *fb*, followed by; HW, hand-weeding; DAS, days after sowing; NS, non-significant; MJ, mega joule

under CT (3.40) than ZT (3.34) and ZT + R (2.66).

Higher cost of cultivation was incurred under CT because of ploughing, harrowing and planking operations (Table 2). The cost incurred on tillage was lower under ZT because of no ploughing before sowing despite the additional cost of glyphosate. Inclusion of sorghum residue under ZT + R involved additional expenditure of ₹2,500/ ha as compared to ZT. Also, the inclusion of pendimethalin with clodinafop + Na-acifluorfen as post-emergence or HW at 30 DAS required additional cost. Gross returns were the highest under ZT + R, followed by ZT and CT. Application of pendimethalin *fb* clodinafop + Na-acifluorfen showed the highest benefit : cost (B : C) ratio, followed by pendimethalin *fb* HW. Evidently, the B : C ratio recorded with unweeded check of CT was the lowest (1.45) as compared to ZT (2.18) and ZT + R (2.41).

Total energy input was more under CT than ZT due to increased number of ploughings (Table 2). The energy spent on ZT and ZT + R was low due to direct sowing with the happy seed-drill without any tillage. More energy was consumed on pendimethalin *fb* HW for employing human labour. Total energy output was directly related to the yield of chickpea. The highest energy output was recorded with pendimethalin *fb* clodinafop + Na-acifluorfen, followed by pendimethalin *fb* HW and pendimethalin alone. The output energy under ZT + R with unweeded check was more compared with ZT and CT under unweeded check. Net returns on energy were the highest under ZT + R as compared to ZT and CT. Similarly, pendimethalin *fb* clodinafop + Na-acifluorfen resulted in higher net energy returns than pendimethalin *fb* HW and pendimethalin alone. Nath *et al.* (2018) reported that, adoption of ZT reduced the energy consumption by 30–40% compared with CT without sacrificing the productivity. Further, ZT + R performed better with less input and resulted in higher net energy returns (Mishra *et al*., 2012).

Energy ratio or energy-use efficiency was comparatively more under ZT + R than

ZT and CT. Application of pendimethalin *fb* clodinafop + Na-acifluorfen showed higher output per unit of input than the other weed-management practices. The lowest efficiency was recorded with unweeded check of CT. Higher energy-use efficiency under pendimethalin *fb* clodinafop + Na-acifluorfen was owing to more yield than the other weed-management practices (Chauhan *et al*., 2017). Pendimethalin *fb* clodinafop + Na-acifluorfen under ZT and ZT + R was 32.7–43.5% more energy efficient than under CT. Grain yield obtained per unit of energy was more under ZT + R than ZT and CT. Pendimethalin *fb* clodinafop + Na-acifluorfen showed the highest energy productivity under all tillage practices, followed by pendimethalin *fb* HW, pendimethalin alone and unweeded check.

It was concluded that, adoption of ZT + R along with use of pendimethalin as pre-emergence *fb* clodinafop + Na-acifluorfen as post-emergence was the most effective practice for improving growth, weed control, economics, and energy-use efficiency in chickpea grown after sorghum in Bundelkhand region.

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