Indian Journal of Agronomy **63** (2): 241–245 (June 2018)

Research Communication

Agri-horti system compatibility and weed management for enhancing sesame (*Sesamum indicum*) production under Vindhyan region of eastern Uttar Pradesh

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Received : October 2017; Revised accepted : February 2018

ABSTRACT

An experiment was conducted during the rainy season of 2015 at South Campus, Banaras Hindu University, Mirzapur, Uttar Pradesh, to study the effect of 3 agri-horticultural systems, viz. guava (*Psidium guajava* L.), custard apple (*Annona squamosa* L.) and open field, and 4 weed-management practices (pendimethalin 750g a.i/ha + hand-weeding (30 DAS); imazethapyr 75g a.i/ha (PoE) + intercultivation (IC) (45 DAS); quizalafop ethyl 40 g a.i/ha (PoE) + IC (45 DAS); and weedy check) on sesame (*Sesamum indicum* L.). Guava agri-horti system recorded higher plant height, biomass, capsule count and seed yield and also recorded less infestation of total weeds; whereas open field recorded the highest weed infestation. Pendimethalin recorded the highest weed-control efficiency (94.9% on density basis and 92.6% on biomass basis) at 40 DAS but reverse results observed after intercultivation as quizalofop-ethyl recorded significantly the lowest infestation of weed and recorded the highest plant biomass, capsule content, test weight and seed yield of sesame. In our study, guava proved a compatible agri-horti system for introduction of sesame and quizalofop ethyl 40 g a.i/ha (PoE) + IC (45 DAS) treatment as best for management of weeds and enhancing productivity.

Key words **:** Agroforesty, Custard apple agri-horticultural system, Fenoxaprop-p-ethyl, Guava agri-horticultural system, Imazethapyr, Oil content

Sesame or til is one of the oldest oil-producing plants, and its seeds have both nutritional and medicinal value as it contains 44-57% oil, 18-25% protein, 13-14% carbohydrate; and because of its quality, it is called “Queen” of the oilseed (Sarkar *et al.* 2010). It is a very versatile crop, grown in a wide range of environments, extending from semi-arid tropics and subtropics to temperate regions (Singh *et al*., 2014). Globally, India is the largest producer, having 24% sesame growing area with an acreage of 1.8 million ha (m ha), and production and productivity of 0.81 million tonnes and 456 kg/ha, respectively (FAOSTAT 2017). However, its productivity is less than the global average (576 kg/ha). Furthermore, due to shrinking land resources along with burgeoning population; it is very difficult to maintain the availability of sesame for the population (Singh *et al*., 2014a). Thus, strategies like horizontal expansion in the area via introduction under agroforestry systems and weed management play a pivotal role to increase its production.

In fact, researches showed that there is ample scope to grow arable crops in the interspaces of the fruit trees, during the initial 5-6 years (Shivran *et al*., 2017), and even further beyond this period by adopting proper lopping management practices. It is worth mentioning that under semi-arid climatic conditions of Vindhyan region, custard apple and guava are very promising agri-horticulture enterprise because both these crops are hardy and withstand heat and prolonged droughts (Singh *et al*., 2014). However, principally, for the introduction of any arable crop under agri-horti system, it is essentially required to identify its ‘alleopathic compatibility’ with agroforestry species (having either beneficial or at least no adverse effect on companion crop) (Rizvi *et al*. 1999).

Moreover, sesame being rainy-season crop-weed competition posses a major threat to its production and limit its productivity. Uncontrolled weed competition reduced the sesame yield by 50–75% (Gupta *et al*., 2015). Weed menace in sesame field is normally tackled by using manual and mechanical methods. Often 2–3 hand-weedings are required to keep the crop free from weeds. Manual weed-

Based on a part of M.Sc. (Agriculture) Agroforestry Thesis of first author submitted to Institute of Agricultural Sciences, BHU, Varanasi, in 2016 (Unpublished)

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ing being arduous, costly and time-consuming and is not possible to be adopted on a large scale (Singh *et al*., 2014). Thus, with increasing crisis of labour, exploring the possibility of herbicidal weed control in sesame deserves attention. Furthermore, species combinations and magnitude of weed communities differ with agroforestry system because trees can regulate germination, growth, development of weeds, through allelopathy (Rizvi *et al*., 1999). Literature reveals no experiment was conducted to evaluate the compatibility of sesame for its introduction under the agri-horti system. Simultaneously, very few experiment findings conducted on the effects of herbicides on sesame production, especially under agro-horti system. Thus, keeping these facts in view, this field experiment was undertaken to study the effect of agri-horti systems and herbicides on the growth of sesame and weeds.

During 2015 (wet season), a field experiment was conducted at Rajeev Gandhi South Campus, Banaras Hindu University (25º 10'N, 82º 37'E, 365 m above mean sea-level), Barkacha, Mirzapur, Uttar Pradesh. The soil of experiment field was sandy clay loam in texture, classified as Inceptisol (Typic Ustochrept), having slightly acidic (*p*H 6.2), low in nitrogen and organic carbon content (0.29 kg/ha) whereas medium in available in P and K contents. The total rainfall received during crop season was 118.0 mm, of which 66.9% between 33 and 35 Standard Meteorological Weeks (SMW) and 18.6% between 37 and 38 SMW. The maximum temperature 38^{o}C was recorded in September, whereas the minimum temperature 23^{o}C was observed in October. In split-plot design, experiment was conducted involving 3-agri-horticultural systems, i.e. custard apple, guava and open-field in main plot and 4 weed-management practices: pendimethalin 750 g a.i./ha (pre) + hand-weeding (HW) at 30 DAS [pendimethalin + HW]; imazethapyr 75g a.i./ha (PoE) + intercultivation (IC) at 45 DAS [imazethapyr + IC]; quizalafop ethyl 40 g a.i/ha (PoE at 20 DAS) + IC at 45 DAS [quizalafop + IC]; and weedy check] were randomly allocated to subplots and replicated thrice. On 28 July 2015, certified seeds of sesame (var. 'Pant 4') were intercropped in alleys of 8-year old custard apple and guava agri-horti systems. In agri-horti systems, custard apple (cv. 'Mammoth') and guava (cv. 'Lucknow 49') was sown at the distance of 7 m × 7 m and 5 m × 5 m, respectively. The details biometrical observation of agri-horti system mentioned in Table 1. The sesame seeds at the rate of 3 kg/ha was sown at 3 cm depth in open furrows made with a manual single row drill, having a row spacing of 40 cm × 5 cm and immediately covered with soil. The crop was uniformly fertilized with urea, single superphosphate (SSP) and muriate of potash (MoP) to supply 50 kg N, 30 kg P_2O_5, 20 kg K_2O/ha. Whole amounts of fertilizers were placed basally, below the seed in the respective row, at the time of sowing. Pendimethalin was applied as pre-emergence (Pre), 1 day after sowing, whereas imazethapyar and quizalafop-ethyl were applied as post-emergence, i.e. 30 DAS. Before spraying, herbicides were dissolved in water at a rate of 500 L/ha, sprayed with a knapsack sprayer fitted with a flat-fan nozzle. The crop was harvested on 19 October 2015. At harvesting, parameters of crop growth [plant height (cm), biomass (g/plant)], yield attributes [capsule count (number/plant) and test weight (g)] and yield [seed yield (kg/ha) and oil content (%)] were recorded. Oil content in grain was determined by extracting the oil in ether by Soxhlet's apparatus. Weed density and weed dry biomass were recorded at 40 DAS, and presented as number/m^2 and g/m^2 respectively. Heterogeneous weed (density and biomass) data were square-root transformed prior to analysis to produce a near normal distribution, although non-transformed means are presented for clarity. The treatment differences were tested by 'F' test of significance on the basis of null hypothesis. Critical differences were worked out at 5% level of probability where 'F' test was significant.

Data on weeds showed significantly the highest biomass of grasses; biomass and density of sedges and broad-

Table 1. Biometrical observation on custard apple and guava plantation

	Plant height (m)		Canopy diameter (m)		Crown length (m)		Girth (m)	
	At time of sowing of sesame	At harvesting of sesame	At time of sowing of sesame	At harvesting of sesame	At time of sowing of sesame	At harvesting of sesame	At time of sowing of sesame	At harvesting of sesame
Custard apple plantation								
Mean	3.69	4.02	3.71	3.97	2.5	2.97	0.29	0.30
Range	3.44 – 4.14	3.7 – 4.56	3.2 – 4.1	3.50 – 4.45	1.95 – 2.9	2.25 – 3.7	0.24 – 0.32	0.29 – 0.33
SD	0.27	0.33	0.36	0.37	0.39	0.61	0.03	0.03
Guava plantation								
Mean	3.77	4.04	4.99	5.41	3.35	3.83	0.33	0.33
Range	3.34 – 4.9	3.6 – 5.2	4.25 – 5.35	4.6 – 5.9	2.9 – 3.7	3.65 – 3.95	0.29 – 0.35	0.29 – 0.36
SD	0.64	0.66	0.51	0.52	0.34	0.12	0.03	0.03

leaf weeds (BLWs); and lowest weed-control efficiency (WCE) under open field (Table 2). Grasses density differed non-significantly with agri-horti system, whereas the biomass showed at par values both in custard apple and guava agri-horti systems. Custard apple agri-horti system significantly suppresses the density as well as biomass of sedges, and biomass of BLWs over guava agri-horti system. Custard apple agri-horti system showed the highest WCE (55.3% on density basis and 54.1% on biomass basis), whereas the lowest WCE (49.7% on density basis and 51.8% on biomass basis) observed under open field. However, sesame crop showed the highest plant height, biomass, capsule count and seed yield under guava agri-horti system (Table 3); whereas sesame crop grown under custard apple agri-horti system revealed significantly lowest plant height and capsule count; and seed yield at par to crop sown in open field. Test weight and oil content of sesame did not differ significantly with agri-horti systems.

In general, crop performance was not good because during the crop-growing period, total rainfall received was much below the normal, i.e. only 120 mm that too unevenly distributed and suspended after 56th days after sowing (DAS) of crop. Sesame exhibited better performance under guava agri-horti system than custard apple owing to following reasons: firstly, guava (Kawawa *et al.*, 2016) and custard apple (Rizvi *et al*., 1980) plantation release certain allelochemicals in root rhizosphere which selectively inhibit the growth of specific plant species and suppresses the growth of crop and weed (Tables 1 and 2), it is hypothesized that guava secreted allelochemicals that have stimulatory effect on sesame, whereas custard apple secreted allelochemicals may have drastically suppressed both sesame and weeds growth. Secondly, custard apple was planted at higher density (row to row distance: 5 m × 5 m) as compared to guava plantation (row-to-row distance: 7 m × 7 m) that resulted in increased competition between the trees and the sesame for water and light. Poor penetration of light in custard apple alleys badly affected the growth of both sesame and weeds. Fadl and Gebauer (2004) are also opined that higher density of agroforestry plantation resulted in increased competition and poor performance by the crop. Thus, in a nutshell, the population density along with allelopathic secretions negatively affects the sesame as well as density and biomass of weeds under custard apple agri-horti system in experimental plots. Furthermore, enhanced crop performance in guava agri-horti system over open field might be owing to higher leaf litter decomposition associated with increased organic matter content, moisture-holding capacity and nutrient concentration, contributing to the higher yield of the annual crop (Hemen *et al*., 2015). Additionally, under the open field condition, crop was subjected to hot desiccating

Table 2. Effect of agri-horti system and weed-management practices on density and biomass of grasses, sedges and broad-leaf weeds in sesame at 40 days after sowing

Treatment	Grasses		Sedges		Broad-leaf weeds		Weed-control efficiency (%)	
	Density (plants/m^2)	Biomass (g/m^2)	Density (plants/m^2)	Biomass (g/m^2)	Density (plants/m^2)	Biomass (g/m^2)	Density basis	Biomass basis
Agri-horti system								
Custard apple	7.3 (60.8)	4.8 (26)	3.6 (13)	1.8 (2)	4.0 (19)	3.4 (13)	55.3	54.1
Guava	7.1 (57.3)	4.8 (27)	4.2 (20)	2.1 (4)	4.1 (21)	4.1 (20)	52.0	53.0
Open field	7.4 (61.5)	5.1 (30)	4.9 (26)	2.4 (6)	4.5 (25)	4.4 (24)	49.7	51.8
SEm±	0.08	0.05	0.03	0.02	0.09	0.08		
CD (P=0.05)	NS	0.18	0.13	0.08	0.36	0.31		
Weed-management practice								
Pendimethalin 750 g a.i./ha (Pre) + HW (30 DAS)	3.4 (11.2)	2.1 (3.9)	1.6 (2.0)	1.3 (0.5)	1.8 (2.7)	1.9 (3.0)	94.9	92.6
Imazethapyr 75 g a.i./ha (PoE) + IC (45 DAS)	8.4 (70.3)	6.0 (35.4)	4.8 (23.0)	2.3 (5.1)	2.4 (5.4)	2.3 (4.8)	48.0	56.7
Quizalofop ethyl 40 g a.i./ha (PoE) + IC (45 DAS)	6.5 (41.6)	4.2 (17.5)	4.8 (23.0)	2.3 (5.0)	5.8 (33.1)	5.4 (29.1)	66.5	62.6
Weedy check	10.8 (116.3)	7.4 (54.6)	5.7 (32.9)	2.7 (7.0)	6.8 (45.9)	6.3 (40.6)	0.0	0.0
SEm±	0.10	0.09	0.09	0.03	0.08	0.07		
CD (P=0.05)	0.28	0.27	0.26	0.09	0.25	0.21		

Values subjected to square-root transformation; original values in parentheses; HW, hand-weeding, IC, inter-cultivation; Pre, pre-emergence; DAS, days after sowing; PoE, post-emergence

Table 3. Effect of agri-horti system and weed-management practices on growth characters, yield attributes and yield of sesame

Treatment	Plant height (cm)	Biomass (g/plant)	Capsule count (number/plant)	Test weight (g)	Seed yield (kg/ha)	Oil content (%)
Agri-horti system						
Custard apple	121.2	27.1	4.9	2.1	67.5	40.62
Guava	145.2	28.7	17.1	2.1	95.1	40.54
Open field	130.9	25.7	10.6	2.1	65.0	40.49
SEm±	3.18	0.25	0.60	0.01	0.81	0.05
CD (P=0.05)	3.18	0.96	2.37	NS	3.18	NS
Weed-management practice						
Pendimethalin 750 g a.i./ha (Pre) + HW (30 DAS)	128.6	27.2	11.1	2.2	81.5	40.62
Imazethapyr 75 g a.i./ha (PoE) + IC (45 DAS)	135.6	26.7	10.2	2.1	76.2	40.49
Quizalofop ethyl 40 g a.i./ha (PoE) + IC (45 DAS)	135.8	29.1	12.6	2.2	95.4	40.57
Weedy check	129.8	25.6	9.4	2.1	54.4	40.51
SEm±	3.54	0.23	0.45	0.005	0.98	0.05
CD (P=0.05)	NS	0.67	1.34	0.01	2.90	NS

HW, Hand-weeding; IC, inter-cultivation; Pre, pre-emergence; PoE, post-emergence

wind vis-à-vis provides the favourable environment for the infestation of weed, probably due to higher initial seed bank of previous years. Both these factors aggravated the moisture stress to the sesame. In fact, the weeds under the dense tree canopy showed decreased transpiration rate due to rise in shading intensity (Singh *et al*., 2014a).

The experimental field during the crop season was infested with bermuda grass [*Cyanodon dactylon* (L.) Pers.], crow footgrass [*Dactylocteniuma aegyptium* (L.) Willd], barnyard grass [*Echinochloa colona* (L.) Link], whereas purple nutsedge (*Cyperus rotundus* L.), diamond flower (*Oldenlandia corymbosa* L.), Indian copperleaf (*Acalypha indica* L.) among sedges and broad-leaf weeds respectively. Sesame grown under weedy check was maximally infested with grasses, sedges and BLWs and showed the lowest WCE and ultimately resulted in poor growth and yield (Table 2). Plant height and oil content differed non-significantly with weed-management practices. Application of quizalofop + IC showed significantly the highest plant biomass, capsule content, test weight and seed yield of sesame as compared to other tested treatments. Application of pendimethalin + HW and imazethapyr + IC resulted statistically similar biomass and capsule count, but the test weight and yield were significantly higher under pendimethalin + HW (Table 3). The density and biomass of sedges were at par value with imazethapyr + IC and quizalofop + IC.

Quizalofop + IC resulted in significantly better crop growth and yield over the other tested treatments. Actually, the crop was predominately infested with grassy weeds and chemically quizalofop performs better in the management of grassy weeds, whereas imazethapyr performs better in the control of many broad-leaf weeds and some grasses and these facts are clearly reflected in management of grassy and BLWs (Table 1) in the experiment. Actually, pendimethalin effectively manages annual grasses and certain small-seeded broad-leaf weeds during initial stage (Kaur *et al*., 2014), but it showed a high rate of degradation and poor persistence, especially under rainy condition, and this would lead to reduced efficacy. Bhaduria *et al*. (2012) also stated that WCE of quizalofop-ethyl was greater than pendimethalin. Therefore, it is hypothesized that application of quizalofop reduced crop-weed competition leads to better crop growth and higher yield of sesame. Besides, IC operation at 45 DAS caused breakdown of capillaries that in turn reduced weeds, evaporation losses from the soil surface and loosen the soil. This will help in holding the precipitation, which occurs on 56 DAS. Thus, quizalofop + IC treatment provides moisture for the relatively longer duration and saves the crop from moisture stress as compared to the other weed-management treatments.

It was concluded that guava-based agri-horti system is more compatible system for production of sesame than custard apple agri-horti system and open field. Further, guava plantation can be effectively utilized for sesame production even after 6 years plantation. And for the weed-management, application of quizalofop ethyl 40 g a.i/ha at 20 DAS + IC at 45 DAS was highly effective.

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