Journal of Applied and Natural Science 9 (3): 1848 -1853 (2017)

JANS

Weed flora dynamics and growth response of green gram (*Vigna radiata* (L.) R. Wilczek) under varied agri-horti system and weed management practices

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Received: December 27, 2016; Revised received: April 11, 2017; Accepted: August 26, 2017

Abstract: Horizontal expansion of pulse production can be achieved by introduction of short duration pulse crop like, green gram (*Vigna radiata* (L.) R. Wilczek) under agri-horti system. Response of green gram under different agri-horti system and weed management practices is lacking. Therefore, an agronomic trial was conducted during monsoon season of 2011 at Agricultural Research Farm, Rajeev Gandhi South Campus, Banaras Hindu University, Barkachha, Mirzapur, Uttar Pradesh, in split plot design, consisting of three agri-horti systems [guava, custard apple and open field] in main plots and six weed management practices [pendimethalin 1000 g/ha (PE), imazethapyr 125 and 200 g/ha (PoE), 1-HW (20 DAS), 2-HW (15 and 30 DAS) and weedy check] were assigned to sub plots and replicated thrice. Green gram variety 'Samrat' was sown as per standard agronomic package of practices on August 5, 2011 in open field as well as within the alleys of, 5-year old, guava and custard apple agri-horti system. Agri-horti systems, did not significantly ($P<0.05$) affect the growth, yield attributes, yield and nutrient content in green gram. The weed management practices significantly affected the CGR, RGR and yield of green gram. Application of imazethapyr 200 g/ha recorded 79.08% reduction in weed biomass and 11.38% lower seed yield as compared to weedy check and 2-HW (15 and 30 DAS), respectively. 2-hand weeding effectively reduced weed biomass (88.07%) and showed highest yield (888.79 kg/ha), and CGR (13.61 g/day) followed by imazethapyr 200g/ha yield (787.66 kg/ha) and CGR (13.14 g/day).

Keywords: Agroforestry, Crop growth rate, Relative growth rate, Weed management

INTRODUCTION

Pulses in India provide good protein to the vegetarians and poor people which constitute major population of the country. India is the world's largest grower and consumer of pulses having total acreage of 26.28 m ha with an annual production and productivity of 18.1 m t and 789 kg/ha (Datta and Singh, 2015), respectively. Despite large production, the net availability of pulses in recent years has declined to 31 gm/day/person; indeed, as per Indian Council of Medical Research (ICMR) guidelines pulses are required to the tune of 65 gm/day/capita) (Reddy, 2009). Thus, to supplement the shortfall in pulses demand, 2.20 lakh tonnes of green gram was imported in India during fiscal year 2007−09 (Reddy, 2009). Therefore, augmentation in pulses production requires an immediate attention to fulfil the demand of burgeoning population. Furthermore, in the 21st century, due to increased human population, there was tremendous pressure on availability of agricultural land for pulse production. Thus, at this juncture, one of the viable options for increased pulse production was its introduction under agroforestry system. Basically, agri-horti system is one of the types of the agroforestry systems where fruit crops are integrated along with field crops. In fact, fruit crops are first preference of farmers under agroforestry system because of short gestation period, regular income, risk cover and aesthetic value etc. (NRCAF, 2000). Moreover, literature showed that, during the initial 5−6 years of agri-horti system, particularly alleys of agri-horti plantation like aonla and custard apple (Gill and Gangawar, 1992) are potentially utilized for production of many pulses and cereals (Prasad *et al*., 2014). It is noteworthy that under semi arid climatic conditions of Vindyan region custard apple (*Annona squamosa* L.) and guava (*Psidium guajava* L.) are very promising agri-horticulture enterprise because both these crops are very hardy, and withstand heat and prolonged droughts (Singh *et al*., 2014). Therefore, if the alleys of these agri-horti are found compatible to pulses production in general and green in particular then it would be beneficial to farmers, in terms of increased income as well as improving soil health (Muthiah, 2004). Green gram (*Vigna radiata* L.) though a very versatile legume crop (Tripathi *et al*., 2012) grown under varied climatic and geographical regions, but its production was seriously constrained with heavy weed infestation. In fact, weed infestation reduced the green gram yield to the tune of 8-57 per cent (Pandey and Mishra,

ISSN : 0974-9411 (Print), 2231-5209 (Online)

2003). Moreover, weeds also harbour the viruses and act as a primary source of inoculums, which causes high incidence of virus-like symptoms. Therefore timely control of weeds is essential for high yield in green gram (Akter *et al*., 2013).

Manual weeding (2-3), common practices for weed management in green gram, but it is time consuming, labour intensive and costly option. Furthermore, with the increased unavailability of labour, particularly during peak weed infestation period, exploring the possibility of herbicidal weed control in green gram deserves attention. Now-a-days, herbicide is an integral part of intensive agriculture in India. Herbicides have been reported to be effective and economically feasible in the smallholder (Muoni *et al*., 2013). Herbicides have the ability to reduce substantially the weeding pressure in short period in carrying out weeding timely. Thorough perspective about agroforestry compatibility with pulses in general, and green gram in particular, will significantly provide substantial implication of agroforestry systems with higher yields. Concurrently, impact of weed management strategies on weed flora and crops would make a better perceptive to improve crop-weed competition. In the light of the above background, the study was designed to investigate the effect of weed management practices and agri-horti system on growth and yield of green gram (*Vigna radiata* (L.) R. Wilczek).

MATERIALS AND METHODS

Experimental site and soil: During monsoon season of 2011, an agronomic field experiment was conducted at Rajeev Gandhi South Campus, Banaras Hindu University ($25^0$10'N latitude $82^0$37'E longitudes and at an altitude 365 meters above mean sea level), Barkacha, Mirzapur, Uttar Pradesh. The experimental field soil was sandy clay loam in texture, classified as Inceptisol (Typic Ustochrept), having slightly acidic (pH 6.2), low in nitrogen and organic carbon content (0.29 kg/ha) whereas, medium in available P and K contents. The total rainfall received during the crop season, i.e. from August to October, was 879.0 mm, out of which nearly 50 per cent received in September.

Trial establishment: In split plot design experiment was conducted involving three agri-horticultural system i.e. custard apple (*Annona squamosa*), guava (*Psidium guajava*) and open field in main plot and 6-weed management practices [pendimethalin 1000 g a.i./ha, imazethapyr 125 and 200 g a.i./ha, 1-hand weeding (20 DAS), 2-hand weeding (15 and30 DAS), and weedy check] were randomly allocated to subplots and replicated thrice.

On August 5, 2011, certified seed of green gram (variety: Samrat) was intercropped in alleys of custard apple and guava agri-horti systems. In agri-horti systems, varieties of custard apple and guava planted are Mammoth and Lucknow-49, respectively. As per the recommendation of Agriculture Department, Uttar Pradesh (DoA, 2012) seed of green gram was sown at the rate of 15 kg/ha at 5 cm depth in open furrows made with a manual single row drill, having a row spacing of 30 cm and immediately covered with soil. Before sowing, the seeds were treated with rhizobium culture as per the procedure suggested by Tripathi *et al*. (2012). Crop was uniformly fertilized with urea, single super phosphate (SSP) and muriate of potash (MOP) to supply 20 kg N, 60 kg P_2O_5 and 40 kg K_2O, respectively. Whole amount of fertilizers were placed basally, below the seed in respective row, at the time of sowing. Pendimethalin was applied as pre-emergence (PRE), within 2-day of sowing, whereas, imazethapyar was applied as post-emergence, i.e. 20 DAS (POST). Before spraying, herbicides were dissolved in water at the rate of 500 L/ha and sprayed with a knapsack sprayer fitted with a flat-fan nozzle. Crop was harvested on October 18-20, 2011.

Biometrical observations: At harvest, various growth parameters such as plant height (cm), relative growth rate (RGR) (g/g/day)from 60-at harvest,crop growth rate (CGR) (g/day) from 60-at harvest, branch count (number/plant) and green trifoliate count (number/plant)], yield attributes [pod count (number/plant), grain count (number/pod)] and yield, grain yield (kg/ha)] parameters were recorded. RGR and CGR were calculated as per the formula suggested by Radford (1967).Weed density and weed dry biomass were rec-

Table 1. Biometrical observations on Custard apple and guava plantation.

	Plant Height (m)		Canopy diameter (m)		Crown Length (m)		Girth (m)	
	At time of sowing of green gram[a]	At harvest of green gram[b]	At time of sowing of green gram[a]	At harvest of green gram[b]	At time of sowing of green gram[a]	At harvest of green gram[b]	At time of sowing of green gram[a]	At harvest of green gram[b]
Custard Apple Plantation								
Mean	2.46	2.63	2.65	2.83	2.57	2.69	0.22	0.22
Range	1.90-2.75	2.11-2.94	2.05-3.10	2.51-3.26	2.0-2.80	2.11-2.93	0.17-0.26	0.17-0.26
SD	0.30	0.30	0.38	0.35	0.23	0.21	0.03	0.03
Guava Plantation								
Mean	2.45	2.65	3.28	3.49	2.73	2.93	0.24	0.24
Range	1.80-3.41	2.0-3.61	1.90-4.37	2.09-4.54	1.76-3.29	1.89-3.43	0.20-0.31	0.20-0.31
SD	0.44	0.45	0.52	0.52	0.45	0.48	0.05	0.05

[a]Observation recorded on 05.08.2011, [b] Observation recorded on 18.10.2011

Table 2. Effect of agri-horti system and weed management practices on density,biomass and weed control efficiency in green gram.

Treatment	Density (number/m^2)[c]			Total Weed Biomass (g/m^2)[c]	Weed Control efficiency (%)[c]
	Broad leaf Weeds	Grasses	Sedges		
Agri-hortisystem					
Guava	7.60 (70.44)	5.20 (34.22)	5.55 (38.67)	3.74 (15.87)	59.23
Custard Apple	9.81 (114.22)	6.52 (53.11)	7.27 (62.44)	5.04 (29.15)	58.25
Open field	5.33 (33.56)	2.90 (11.11)	2.64 (9.78)	2.77 (8.46)	59.89
SEm±	0.10	0.20	0.28	0.04	-
CD (P=0.05)	0.43	0.86	1.17	0.17	-
Weed management practices					
Pendimethalin 1000 g/ha	9.64 (96.89)	7.23 (54.67)	7.57 (60.89)	5.26 (27.80)	32.64
Imazethapyr 125 g/ha	8.26 (72.44)	3.86 (17.33)	5.09 (33.78)	3.69 (13.72)	69.77
Imazethapyr 200 g/ha	6.25 (42.67)	3.19 (13.78)	3.64 (18.67)	2.91 (9.05)	82.90
1-Hand Weeding (20 DAS)	8.18 (71.11)	5.12 (26.67)	5.01 (29.33)	3.63 (12.80)	69.96
2- Hand Weeding (15&30 DAS)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.12(4.89)	99.49
Weedy Check	12.14 (153.33)	8.83 (84.44)	8.63 (79.11)	6.47 (43.27)	0.00
SEm ±	0.24	0.24	0.25	0.10	-
CD (P=0.05)	0.69	0.71	0.72	0.28	-

[c] Data recorded at 40 DAS, Data are subjected to square root transformation, Original (non-transformed) values given in parenthesis.

orded at 40 DAS, as per the procedure given by Singh and Saini (2008) and presented as number/m^2 and g/ m^2, respectively. For estimation nitrogen (N), phosphorus (P) and potassium (K) uptake by green gram and weeds, first N, P, and K content in plant samples were determined. Nitrogen content in plant samples (crop and weeds) were estimated by micro-Kjeldahl method. However, phosphorus was estimated colorimetrically following the vanadomolybdate method and potassium content in the aliquot of the triple acid extract was estimated by emission spectrophotometry using EEL flame photometer (Jackson, 1973). Later on, nutrient uptake by crop and weeds were computed as per formula mentioned hereunder:

$$Nutrient Uptake\ (kg ha^{-1}) = \frac{Nutrient content\ (\%)\ x dry matter accumulation (kg ha^{-1})}{100}$$

Statistical analysis: Data collected on crop and weed growth statistically analyzed as per procedure suggested by Gomez and Gomez, 1984. 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 per cent level of probability where 'F' test was significant.

RESULTS AND DISCUSSION

Effect on weed growth: The dominant weeds associated with the green gram among grasses were love grass (*Eragrostis pilosa* (L.) Beauv.), little barnyard grass (*Echinochloa colonum* (L.) Link) whereas, old world diamond flower (*Oldendandia corymbosa* L.), hairy spurge (*Euphorbia hirta*) and purple nutsedge (*Cyperus rotundus* L.) among broad leaved weeds and sedges, respectively.

Data indicated that both density and biomass of broadleaved, grasses and sedges were recorded significantly higher under custard apple agri-horti system as compared to guava agri-horti system and open field system (Table 2). In fact, critical analysis of data further revealed, under open field condition *E. pilosa* was completely absent, whereas, *O. corymbosa* infestation was also drastically reduced as compared to two agri-horti systems. This might be due to micro-climate condition within the agri-horti system varies with open field in terms of higher soil moisture retention because of comparatively higher soil organic matter and less interception of direct solar radiation this will favours germination and growth of total weeds in general and *O. corymbosa* and *E. spp.* in particular (Corbineau and Come, 1982; Chauhan, 2013).

Application of 2-hand weeding (15 and 30 DAS) recorded significantly lowest density and biomass as compared to other treatments. This treatment gave best results because weeding was performed during critical period of crop-weed competition (i.e. first 30 days of crop growth) (Singh *et al*., 1991), thus cascading effect observed in terms of better crop growth and crop lead suppression of weeds. Application of imazethapyr 200 g/ha effectively reduced biomass and density of total weeds in general and broad leaf weed (BLW) (*E. hirta* and *O. corymbosa*) and grasses (*E. pilosa* and *E. colonum*) in particular, and was also found significantly superior over application of pendimethalin 1000 g/ha and 1-hand weeding (20 DAS). As a post-emergence herbicide imazethapyr has more efficacy against the broadleaf weeds and a few grasses and least effect on legumes (Krämer and Schirmer, 2007) and has long persistence in the soil (Savage and Jordan, 1980; Goetz *et al*., 1990) and less volatile (Zimdahl, 2007). Similarly, Deore et al. (2007) tested nine treatments i.e. imazethapyr 50, 75, 100 and 200 g /ha, chlorimuron ethyl

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

Treatment	Plant height (cm)	Crop growth rate (g/day)	Growth attributes: Relative growth rate (g/g/day)	Growth attributes: Green trifoliate count (No./plant)	Growth attributes: Branch Count (No./plant)	Yield attributes and Yield: Pod count (No./plant)	Yield attributes and Yield: Grains count (No./pod)	Yield attributes and Yield: Grain yield (kg/ha)
Agri-horti system								
Guava	40.43	11.71	0.00291	7.41	3.54	12.74	10.02	715.34
Custard Apple	40.40	11.69	0.00317	7.29	3.44	12.53	9.92	691.91
Open field	40.81	11.89	0.00334	7.60	3.57	12.83	10.09	728.41
SEm±	0.06	0.09	0.00150	0.03	0.07	0.06	0.07	6.63
CD (P=0.05)	0.24	NS	NS	0.12	NS	NS	NS	NS
Weed management practices								
Pendimethalin 1000 g/ha	37.29	10.61	0.00356	6.53	3.22	11.09	9.54	631.97
Imazethapyr 125 g/ha	39.25	10.68	0.00201	6.56	3.40	12.84	9.86	757.63
Imazethapyr 200 g/ha	43.17	13.14	0.00442	8.93	3.82	13.84	10.49	787.66
1-Hand Weeding (20 DAS)	42.16	12.24	0.00238	7.58	3.56	13.24	9.90	767.87
2- Hand Weeding (15&30DAS)	46.03	13.61	0.00183	9.60	4.20	14.87	10.97	888.79
Weedy Check	35.39	10.30	0.00465	5.40	2.91	10.33	9.31	437.39
SEm ±	0.33	0.37	0.00183	0.13	0.07	0.14	0.05	13.86
CD (P=0.05)	0.97	1.07	NS	0.38	0.19	0.41	0.13	40.03

Table 4. Effect of agri-horti system and weed management practices on nutrient uptake of green gram and weed.

Treatment	Nutrient uptake by green gram (kg/ha): Nitrogen (N)			Phosphorous (P)			Potassium (K)			Nutrient Uptake by Weed (kg/ha)		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total	N	P	K
Agri-horti system (S)												
Guava	23.34	22.14	45.47	2.49	4.24	6.73	7.47	45.43	52.90	2.27	0.34	3.06
Custard Apple	22.32	21.10	43.42	2.31	3.84	6.15	7.14	44.20	51.34	3.84	0.55	5.23
Open field	23.74	22.99	46.72	2.61	4.71	7.32	7.78	47.07	54.85	1.23	0.18	1.68
SEm±	0.28	0.10	0.24	0.03	0.20	0.19	0.11	0.63	0.57	0.18	0.02	0.20
CD (P=0.05)	NS	0.42	1.03	0.13	NS	0.79	0.45	NS	2.42	0.75	0.07	0.83
Weed management practices (W)												
Pendimethalin 1000 g/ha	20.29	19.77	40.06	2.16	3.63	5.79	6.52	40.62	47.14	3.59	0.54	5.00
Imazethapyr 125 g/ha	24.28	22.70	46.98	2.65	4.34	6.99	7.97	47.11	55.09	1.53	0.22	2.10
Imazethapyr 200 g/ha	25.82	24.38	50.20	2.73	4.94	7.68	8.35	50.06	58.41	0.52	0.08	0.73
1-Hand Weeding (20 DAS)	25.11	23.75	48.86	2.70	4.62	7.32	8.03	49.54	57.57	1.87	0.26	2.59
2- Hand Weeding (15&30 DAS)	29.46	27.15	56.61	3.17	5.36	8.53	9.44	55.73	65.17	0.47	0.07	0.62
Weedy Check	13.82d	14.70	28.52	1.41	2.68	4.08	4.49	30.34	34.82	6.71	0.98	8.90
SEm±	0.56	0.53	0.95	0.07	0.19	0.25	0.16	1.10	1.18	0.23	0.02	0.25
CD (P=0.05)	1.80	1.53	2.73	0.20	0.55	0.71	0.46	3.19	3.40	0.67	0.06	0.72

9.37 g/ha, fenoxyprop ethyl 67.5 g /ha, pendimethalin 750 g /ha, fluchloralin 1 kg /ha and weedy check and found that maximum weed control efficiency was recorded under Imazethapyr 200 g/ha (89.26 per cent) and followed by Imazethapyr 100 g/ha (83.65 per cent). Rainfall occurs within 12-hr of pendimethalin application; it was earlier reported that after application of pendimethalin rainfall event enhances the degradation and reduced its efficacy (Savage and Jordan,1980; Zimdahl *et al*.,1984). Moreover, in our previous experiment, Singh *et al*. (2014) reported imazethapyr 125 g/ ha effective for weed management and gave higher yield of green gram. However, to further increase the weed control efficiency and weed index, higher rate of application (imazethapyr 200 g/ha) was tested in present study, and was found to be optimum for higher weed smothering and higher yield of green gram. Weed control efficiency recorded higher in 2-hand weeding (15 and 30 DAS) (99.49%) followed by imazethapyr 200 g/ha (82.9%) among rest of the weed management practices.

Effect on crop growth, yield attributes and yield: Agri-hortisystem has no significant effect on growth, yield attributes and yield of green gram, except plant height and number of trifoliate leaf (Table 3). This data clearly implies that green gram is compatible with guava and custard apple based agri-horti and can be successfully grown without any significant yield reduction. Reasons for non-significant difference between the systems might be due to firstly, both the agri-horti system having same age i.e. 5-years old and almost similar in various growth traits (Table 1), thus crop grown under both the canopy faces similar microclimate, secondly, agri-horti system was pruned prior to sowing and moreover, nearly 1.5 metre distance was maintained between the plantation row and plots of green gram, to reduced shading effect, thus crop faces partial shading effect and perform similar to crop grown under open field condition. That's why there is slightly higher yield under open field condition, but it is at par with agri-horti systems.

Application of 2-hand weeding recorded higher plant height, RGR, CGR, branch count and green trifoliate count, pods/plant, grains/pod, and grain yield of green gram and closely followed by imazethapyr 200 g/ha (Table 3), and significantly superior over rest of the treatments. Higher growth and yield observed under 2-hand weeding treatment because under this treatment weeding operations are performed at critical period of crop-weed competition, that will lead better weed suppression and higher weed control efficiency (Table 3), which in turn resulted in higher natural resource allocation to the crops, thereby crop exhibited more vegetative growth, enhanced yield attributes and yield (Table 3) This data was in conformity with the findings of Singh and Kumar (2008). Agri-horti system did not significantly affect the CGR and RGR. In weed management practices RGR recorded less in 2-hand weeding (duration: 60 DAS to at harvest) among weed management practices. It is due to that at gradual elevate in growth of RGR during vegetative phase and falls off during harvesting phase shows the proper dry matter accumulation, which leads to attend maximum yield, suggested by Hunt (1978).

Effect on nutrient uptake in green gram and weeds: Data clearly showed, total N, P and K uptake by green gram was recorded significantly under open field followed by guava and custard apple. Whereas, vice versa trend observed in uptake of N, P and K by weeds (Table 4). In fact less crop-weed competition resulted in high crop dry matter accumulation, which in turn leads to higher nutrient uptake by green gram in open field and vice versa phenomenal also true in case of weeds in custard apple.

Application of 2-hand weeding showed significantly highest nutrient uptake by the green gram, whereas imazethapyr 125 and200 g/ha, 1-hand weeding (20 DAS) and pendimethalin 1000 g/ha applied in green gram showed similar nutrient uptake. Higher nutrient uptake by 2-hand weeding associated with poor crop-weed competition; thereby enhanced vegetative growth and dry matter accumulation by crop. Obviously higher dry matter accumulation leads to higher nutrient uptake because nutrient uptake is function of nutrient content and dry matter accumulation. Stoimenova (1995) in view that decreased nutrients uptake by the crop was noticed with increase in severity and duration of weed infestation. Similarly, Kumar (2011) also reported that lowest nutrient uptake by crop was observed under weedy check and this could be due to highest weed biomass. Nutrient uptake by weeds was observed maximum and minimum under weedy check and pendimethalin 0.75 kg/ha, respectively. Actually, nutrient uptake is a product of nutrient concentration and dry matter accumulation, nutrient content, in generally, did not vary with the treatments, so the dry matter accumulation play a vital role in nutrient removal/ uptake. Thus, higher biomass under weedy check showed higher nutrient uptake and vice-versa noticed in case of pendimethalin. This result was in agreement with Kaur *et al*. (2010) who have reported highest removal of N, P and K by weeds was noted under weedy check (68.90 kg N, 19.29 kg P and 77.17 kg K/ha), followed by Quizalofop-ethyl 35 g/ha (35.66 kg N, 12.39 kg P and 34.50 kg K/ha) and significantly ($P<0.05$) lowest under pendimenthalin 0.75 kg/ha (8.70 kg N, 3.17 kg P, and 11.57 kg K/ha).

Conclusion

From this study, we can conclude that custard apple and guava agri-horti system has ample scope for introduction of pulse crop. Moreover, these agri-hortisystems are found compatible for green gram production, without any significant reduction in crop

growth, nutrient content and yield attributes and yield of greengram. But, definitely weed flora dynamics changes with the agri-horti system. Although, 2-hand weeding (15 & 30 DAS) have the higher weed suppression (WCE 99.49), crop growth and yield (888.79 kg/ha) of green gram, however, under labours scarcity, application of imazethapyr 200 g/ha (POST) also gave comparable weed smothering (WCE 82.90) and enhanced yield attributes and yield (787.66 kg/ha) of greengram.

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