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Effect of lac culture on seed quality traits of Pigeonpea [*Cajanus cajan* (L.) Millsp.]

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Abstract
Pigeonpea (*Cajanus cajan*) commonly known as *arhar*, red gram or *tur* of family Fabaceae is an important source of protein, carbohydrates, B-group vitamins, and certain minerals (iron and iodine).It is also known for lac culture, harboring *rangeeni* strain of Indian lac insect (*Kerria lacca* Kerr). The present study was planned to investigate the effect of lac culture on seed quality in selected germplasm. Lac culture decrease 100 seed weight (5.4 %) and seed yield (10.5 %). Higher income has been achieved from seed yield along with lac cultivation on MAL 13, IPA 9-1 and KA 9-2 but seed contributed most in income. However, Assam local 1, Assam local 2 and RCMP 5 lines of pigeonpea had significantly higher profit percent under lac cultivation where income from lac culture contributed the most. Lac culture decreases seed soluble protein (10.3 %) and starch (14.7 %) and increases total sugar and free phenol by 8.8 % compared to control. Thus, it can be concluded that farmers will get more income from these three germplasm through combination of seed as well as lac culture than from seed as sole crop.

Keywords: Pigeonpea, *Cajanus cajan*, seed quality, lac insect, *Kerria lacca* (Kerr.)

Introduction
Insects, in context to agriculture have many faces; from harmful pests to beneficial nature. The economic importance of insects is known to mankind since time immemorial and has influenced our life in many ways. Products from industrially important insects provide livelihood to lakhs of farmers especially belonging to the down-trodden strata of the society. The best known beneficial insects like honeybees, silkworm and lac insect are nature's gift to mankind which provides extra income to the people engaged in agriculture. Indian lac insect (*Kerria lacca* Kerr.) belonging to the family Tachardiidae (=Kerriidae), a specialized group in Superfamily Coccoidea (Hemiptera: Sternorrhyncha) is cultivated for its commercial components resin, wax and dye. It has been exploited by many people especially tribal's residing around the forest areas of Indian states Jharkhand, Chhattisgarh, Madhya Pradesh, West Bengal, and Odisha. Lac is also produced in small quantity in Bangladesh, Myanmar, Thailand, Combodia, Vietnam, and parts of China. Tree species like *Kusum* (*Schleichera oleosa*), *Ber* (*Ziziphus mauritiana*), *Palas* (*Butea monosperma*) are the major host plant for lac culture [1, 2, 3, 4, 5]. The development of lac-insect on host plant is dependent and influenced by abiotic and biotic factors [6].
Pigeonpea [*Cajanus cajan* (L.) Millsp] commonly known as *arhar*, red gram or *tur* is a legume crop belonging to the family Fabaceae and subfamily Papilionaceae. It is an important source of protein, carbohydrates, B-group vitamins, and certain minerals (iron and iodine). India ranks first in area (74%) and production (63%) in the world, where it is mostly consumed as dehusked splits or *dal* [7]. It is also an important lac host-plant in Assam, North-East India [8]. The trials to harness its potential for lac production were initiated way back in 1950s by ICAR-Indian Institute of Natural Resins and Gums (erstwhile Indian Lac Research Institute), Ranchi, India. It was concluded that *rangeeni* strain of *K. lacca* (Kerr) was most suitable for lac production on pigeonpea (Fig. 1a) [9]. It is to mention here that there are two strains of Indian lac insect, *K. lacca* (Kerr.), *kusmi* and *rangeeni*, characterized by their life cycle and their host plant [10,11]. Pigeonpea also is a host for *Kerria chinensis chinensis* lac insect (Fig1b) in North-East Indian states like Assam and Meghalaya [12]. It is a popular lac insect host-plant in Yunnan province of China also [13].The pigeonpea crop can be exploited for grain as well as lac resin and it was reported that lac cultivation on pigeonpea reduces 100 seed weight and grain yield per plant. However, the seed yield loss can be compensated by additional income received from selling the lac resin [11].

Considering the fact that Pigeonpea is a major pulse consumed across the country, it was felt essential to study whether lac cultivation affect its seed quality.

It was also important to investigate which of the germplasm was better suited for lac cultivation and also for grain production giving increased remuneration to the farmers. Hence, the present study was planned to investigate the effect of lac cultivation on seeds quality of different pigeonpea germplasm.

Fig.1 Lac insect on Pigeonpea (*C. cajan*) : (a) *K. lacca* Kerr (*Rangeeni* strain) at IINRG, Ranchi; (b) *Kerria chinensis chinensis* in Meghalaya

Materials and Methods

The evaluation study was initiated with twenty-nine germplasm lines of pigeonpea during 2012-13 at ICAR-IINRG, Ranchi (India) to identify the potential line(s) for *rangeeni* lac cultivation along with grain yield. The germplasm included cultivars/ accessions/ collections from NE region of Assam and Manipur (India), ICRISAT (India), including medium and late maturing varieties of this region and high yielding advance lines from All India Coordinated Research Project (AICRP) on pigeonpea. Seeds were sown in randomized block design with three replications during July at IRF in paired row system with 75 cm distance between plants and within paired rows and 150 cm distance between paired rows. Plant population of 11850 per hectare was maintained. Recommended package of practices was adopted for lac cultivation along with grain yield [9].Adequate measures were taken for weed free experimental plots during initial period of two months for proper vegetative growth of plants. Medium maturing germplasm flowered in October-November and late maturing in January-February. *Rangeeni* strain of broodlac was inoculated in October- November @ 50 gram per plant. Broodlac means 'healthy lac encrustation consisting of gravid females about to produce young ones: similar to seeds of agriculture crops. Pods matured in March- April were harvested through hand-picking in control (no lac) and lac inoculated plants separately and dried. Yield attributing traits (viz., 100 seed weight in gram and seed yield per hectare in quintal) were recorded. Broodlac was harvested from each plant and weighed and its yield output ratio was calculated. Resin deposited around the stem of each plant was scraped and calculated to scrapedlac per 100 gram broodlac and scrapedlac yield per hectare. Scrapedlac means lac resin obtained after scrapping from sticks of lac host. Based on performance of twenty-nine germplasm of pigeonpea, only ten germplasm was selected and sown in RBD with three replications. Out of these, 4 germplasm (Assam local 1, Assam local 2, RCMP2, RCMP5) are from North East region, 4 germplasm (IPA 8-2, MAL 13, IPA 9-1, KA 9-2) are of high grain yielding advance lines and two checks (Bahar and Birsa Arhar 1) were taken for study. Biochemical parameters viz., total sugar, starch, soluble protein and free phenol were analyzed in seeds of these germplasm in lac insect inoculated condition and control (plants without lac insect) for two consecutive years in three replications. The total sugar was extracted using 80% hot alcohol [14] and determined by Nelson's arsenomolybdate method using improved copper reagent of Somogyi [15, 16]. Soluble protein was estimated by Lowry's method [17] and free phenol was determined using Folin-Ciocalteau reagent method [18]. Starch was determined by the anthrone method [14, 19]. Starch content was calculated by multiplying the glucose values by 0.9 [20]. Three years data on seed yield and lac attributing traits and two year data on biochemical traits was pooled and analyzed by using standard statistical packages for drawing conclusive result.

Results and Discussion

Pigeon pea is an important legume crop of rainfed agriculture in the semiarid tropics. The ability of pigeonpea to produce economic yields under soil moisture deficit makes it an important crop of dry land agriculture. Pigeonpea is also a favorable host for lac insect (*Kerria lacca* Kerr.). Complex character like yield have several component characters but two important traits viz.,100 seed weight along with seed yield was taken for screening germplasm. Though lac cultivation influence the seed yielding capability of host plant, but the economic return from both seed and lac yield has its significance for identifying suitable germplasm of pigeonpea. Seed yield along with lac will augment the income of farmers from dry land agriculture.

Seed yield and lac yield

There was a significant difference in 100 seed weight and seed yield among selected germplasm of pigeonpea. Hundred seed weight ranged from 9.1 g - 11.7 g in lac inoculated germplasm lines and 9.8 g - 12.9 g in control. The average seed yield in lac inoculated condition was 12.2 q/ ha as compared to 13.5 q/ ha in control (Table 1). This show that the lac cultivation on pigeonpea influenced significantly seed yielding traits under investigation. On an average, lac culture on pigeonpea reduced 100 seed weight and seed yield by 5.4

and 10.5 percent, respectively. KA 9-2 (11.7g & 12.9g) and Assam Local 2(11.2g & 12.1g) maintained high 100 seed weight in both situations as compared to check Bahar (9.9g & 10.5g),whereas KA9-2 and MAL 13 had relatively higher seed yield in both inoculated (19.9 q/ha&18.7 q/ha) as well as control (21.7 q/ha&19.5 q/ha) condition as compared to check Bahar (10.7 q/ha&12.4 q/ha).Decrease in 100 seed weight was observed low in IPA 9-1 (-1.4 %) and RCMP 2 (-2.6%), whereas MAL 13 (-3.7 %) and IPA 8-2 (-5.7%) recorded lesser amount of decrease in seed yield. Reduction in 100 seed weight (13.0 %) and seed yield per plant (12.1%) due to lac insect cultivation on pigeonpea germplasm was reported [11]. Seed yield loss due to aphid infestation in Mustard-rapeseed crops was reported [21, 22, 23].

Table 1: Lac production potential of selected lines of pigeonpea and its effect on grain production

Selected germplasm	100 seed weight (g)			Seed yield per hactare (q)			Broodlac yield out put ratio	Scrapedlac /100 g broodlac	Scraped lac/ha (Kg)
	Inoculated	Control	Decrease (%)	Inoculated	Control	Decrease (%)			
BirsaArhar 1	11.10	11.77	-5.67	10.05	12.15	-17.34	2.2	43.6	258
Bahar (C)	9.93	10.50	-5.40	10.74	12.44	-13.66	2.8	45.8	272
Assam local 1	9.47	10.00	-5.33	7.27	8.58	-15.27	3.15*	48.5	287
Assam local 2	11.23	12.13	-7.42	11.19	12.13	-7.77	3.45*	51.6*	306
RCMP 5	9.07	9.80	-7.48	9.11	9.86	-7.63	2.9	53.7*	318
RCMP 2	9.90	10.17	-2.63	10.22	11.20	-8.75	2.8	40.1	238
IPA 8-2	9.30	9.83	-5.42	12.70	13.48	-5.73	2.5	42.2	250
MAL 13	10.40	10.80	-3.70	18.74	19.45*	-3.66	2.5	39.6	235
IPA 9-1	9.70	9.83	-1.35	11.62	14.00	-16.98	2.5	54.5	323
KA 9-2	11.70	12.87	-9.07	19.88	21.67*	-8.26	2.9	49.7	294
Mean	10.18	10.77	-5.35	12.15	13.50	-10.50	2.6	46.9	278
CD Germ	0.99			4.17			0.27	5.70	29.12

Assam local 1and 2 had significantly higher broodlac yield output ratio (3.2 and 3.5) as compared to check Bahar (2.8), however it ranged from 2.2 (Birsa Arhar 1) to 3.5 (Assam local 2). The scrapedlac, the raw material for industry, varied with germplasm and its yield was significantly higher in Assam local 2 (306 kg/ha), RCMP 5(318 kg/ha) and IPA 9-1(323 kg/ha) with respect to check Bahar (272 kg/ha) among selected germplasm (Table 1).Farmers will get significantly higher net income from lac cultivation on these three germplasm (Table 2). Significantly higher income can be achieved from IPA 8-2, Mal 13, IPA 9-1 and KA 9-2from sole crop for seeds as compared to Bahar as these are high seed yielding advance lines of pigeonpea. Higher income has also been achieved from seed yield along with lac cultivation on MAL 13, IPA 9-1 and KA 9-2 but most of the contribution in income came from selling seeds. When germplasm used for getting seed along with lac, farmers always desired to acquire additional income in comparison to sole crop for seed. Significantly higher additional income had been achieved from lac culture on Assam local 2 (Rs 11320/ ha) and RCMP 5 (Rs 14625/ ha) as compared to check Bahar (Rs 1074/ ha). While calculating profit percent with respect to additional income from lac cultivation and income from selling seed as sole crop Assam local 1 (12.8 %), Assam local 2 (17.1 %) and RCMP 5 (27.2 %) had significantly higher profit percent as compared to Bahar (1.6 %) (Fig 2).

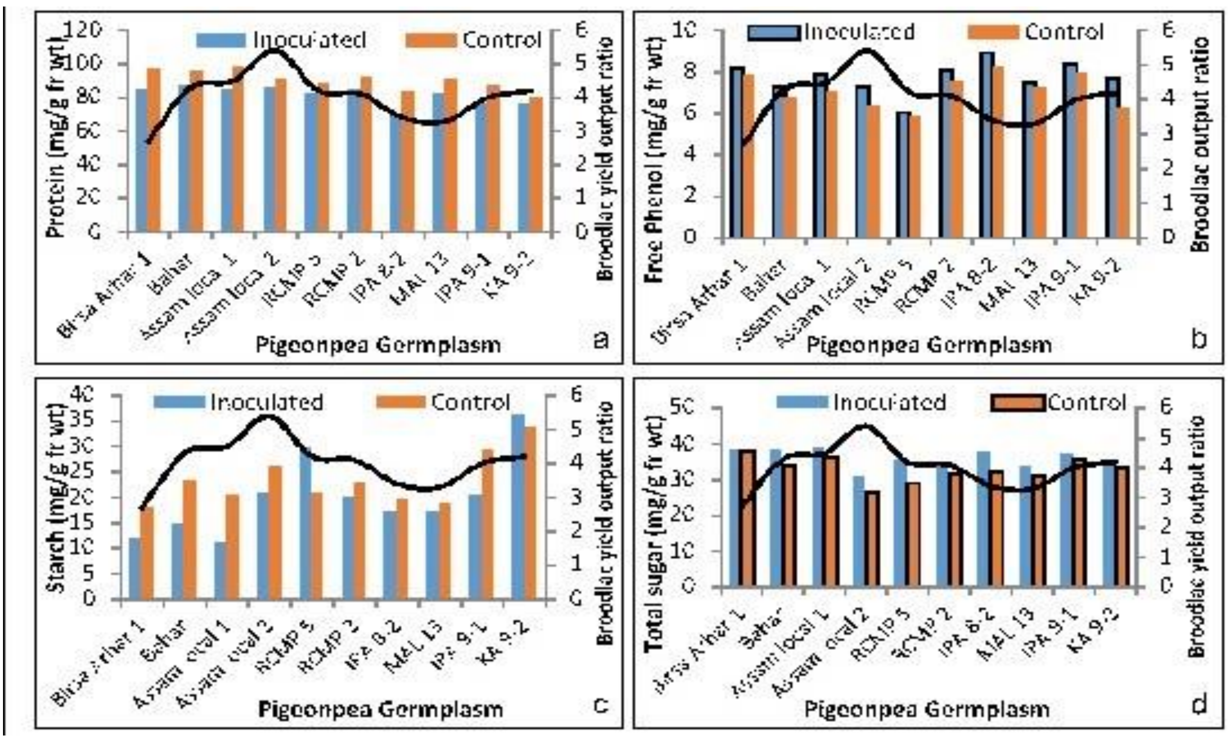

Fig 2: Change in quality traits of seeds of pigeonpea germplasm under lac culture(a) Protein; (b) Free Phenol; (c) Starch and (d) Total sugar

Table 2: Profit in lac culture on pigeonpea as compared to sole crop

	Income from scrapedlac (Rs)	Net income* from scrapedlac (Rs)	Income from Seed+ scrapedlac (Rs)	Income from Seed (Rs)	Additional income (Rs)	Profit %
Bahar (C)	48881	10332	68854	67779	1074	1.59
Assam local 1	51680	13130	52740	46747	5993	12.82*
Assam local 2	55004*	16454*	77420	66100	11320*	17.13*
RCMP 5	57276*	18726*	68368	53743	14625*	27.21*
RCMP 2	42745	4195	59887	61030	-1143	-1.87
IPA 8-2	45056	6506	75738	73441*	2297	3.13
MAL 13	42283	3733	105870*	106012*	-142	-0.13
IPA 9-1	58111*	19561*	82916*	76315*	6601	8.65
KA 9-2	52959	14409	122768*	118111*	4657	3.94
Mean	50051	11501	77728	**73552**	**4176**	**6.7**
CD	5243	5243	16444	2335	9647	8.7

Cost of cultivation of lac= Rs 3855 per ha, Broodlac required= 296/ ha, Plant population= 11850 per ha Purchase price of broodlac= Rs 120/ kg, Sale price of Scrapedlac= Rs 180/-, Minimum support price of pigeonpea seed= Rs 50.50/ kg
*Net income from scrapedlac =Price of scrapedlac - Cost of lac cultivation

Protein
Pigeonpea seed is an important source of protein in human diet [24, 25, 26]. When protein content in seeds of pigeonpea germplasms was analyzed in inoculated vis-à-vis un-inoculated condition the overall 10.25%decrease in seed protein was observed (Table3). Its depletion was less in Assam local 2 (5.0%) and KA 9-2 (5.5%) germplasm as compared to others (Fig. 3a). Aphid feeding on wheat decreases bread making quality of seed due to lower gliadin/glutenin ratio was reported [27]. Decrease in seed protein level in Mustard (*Brassica juncea*) after infestation with aphids was reported [28]. There was report that lac insect (*K. lacca*) feeding on pigeonpea decrease in seed protein content [11]. Apart from proteins role in plant growth as a building material, they also had a role in defense against herbivore attack such as proteinase inhibitors [29, 30, 31, 32]. The decrease in seed protein may be attributed to the reconfiguration of leaf protein towards production of defense proteins which may acts against lac insect feeding.

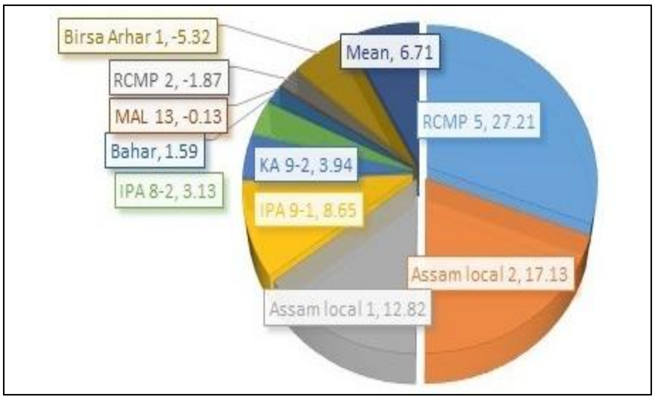

Fig : Profit percentage in lac culture as compared to sole crop of pigeonpea

Table 3: Percent increase/decrease in quality traits of seeds of pigeonpea after lac culture

Selected germplasm	Soluble protein	Starch	Total Sugar	Free Phenol
BirsaArhar 1	-12.80	-34.34	-0.09	4.46
Bahar	-8.76	-35.61	12.87	8.18
Assam local 1	-14.13	-45.91	6.11	11.74
Asham local 2	-4.98	-20.37	17.00	14.51
RCMP 5	-6.90	40.67	21.54	3.42
RCMP 2	-8.06	-13.57	7.34	7.97
IPA 8-2	-18.28	-11.81	17.79	8.51
MAL 13	-10.09	-7.59	7.59	3.79
IPA 9-1	-12.72	-30.61	3.16	5.02
KA 9-2	-5.49	6.50	-0.10	22.89
Mean	-10.25	-14.67	8.77	8.81

Sugar
Carbohydrates are the major components of seed cotyledon in pigeonpea [24]. When total sugar content in the seeds was determined it was found that there was an 8.8% average increase in all the germplasms except Birsa Arhar 1 and KA 9-2 where marginal decrease was observed (Table 3 & Fig. 3d). Several sugar-induced resistance genes have been found signifying the role played by sugars in signaling. Sucrose, glucose, and fructose act as specific regulatory signals on the wound [33]. It has been reported that photosynthetic activity increased in unattacked leaves following damage by defoliating herbivores [34]. The increase in seed sugar content in all the pigeonpea germplasm indicates that sufficient quantities of primary metabolites are produced in the leaves which are trans-located for seed development, used for defense against lac insect and for its own growth and development.

Starch
Starch accumulates in the plants as nonstructural carbohydrates (NSC) to support respiration and growth as well as metabolic processes generating plant defenses [35]. These stored NSCs are utilized by the plants to replace tissues lost to pests and other stresses [36]. When starch content was determined in the seeds of lac inoculated plants and compared with lac uninoculated plants it was found that lac insect feeding decreases its content (14.7% on an average) in all the germplasms except RCMP 5 and KA 9-2where it increased after lac culture (Table 3 & Fig. 3c). This suggests that sap sucking lac insect induces the starch degradation pathway in

order to increase sugar concentration in sap of the host plant during night time, ensuring the constant supply of sucrose during dark period.

Free Phenol

Secondary metabolites like free phenol which plays role in resistance against herbivore, increase upon infestation of any insect pest [37,38]. The high levels of free phenol in lac culture are transmitted in seed also which is evident from its increased level in seeds of the pigeonpea germplasm (Table 3& Fig. 3b). The interaction study between germplasms and lac insect revealed that stress imposed by lac insect had significant effect on free phenol content. The expression of genes involved in plant defense in respect to aphids and whiteflies attack are also reported [39, 40]. The lac insect inoculation also increases free phenol content in leaves of pigeonpea germplasm [11].

Conclusion

The response of different germplasm to lac culture was different and varied with the parameters studied. Those germplasm which recorded high broodlac yield output ratio and scrapedlac yield showed more reduction in seed quality parameters except total sugar. This means that as insect load increases there is reduction in basic yield attributes. In other words lac insect compelled host plants to reconfigure its resources towards its own survival rather than growth and yield of host plants. The additional income from lac culture were obtained from Assam local 2 and RCMP 5in comparison to check Bahar and have potential for lac culture along with seed yield. Hence, with average broodlac output ratio of 3.2, scrapedlac yield of 52.6per 100 gram broodlac inoculated along with optimum seed yield of 10.1 q/ha, farmers will get more income through lac culture than income from sole crop for seed.

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References

1. Krishnaswami S. Lac through the ages. A monograph on lac Mukhopadhyay B and Muthana MS (eds.). Indian Lac Research Institute, Namkum, Ranchi, Bihar, India, 1962, 1-13.
2. Ramani R. Morphology and anatomy of lac insects. In: Recent Advances in Lac Culture, Sharma KK and Ramani R (eds.). IINRG, Ranchi, India, 2011, 37-45.
3. Shamim G, Ranjan SK, Thamilarasi K, Mohanasundaram A, Sharma KK, Ramani R. Phylogenetic study of Lac Insects of Kerria spp. using intron length polymorphism (EPIC-PCR). Journal of Entomology and Zoology Studies. 2014; 2(4):258-264.
4. Ghosh J, Lohot VD, Singhal V, Ghosal S, Sharma KK, Ramani R. Genetic diversity in *ber* (*ziziphus mauritiana* lam.) varieties for lac production, The Bioscan. 2015; 10(4):1905-1908.
5. Ghosh J, Lohot VD, Singhal V, Sinha NK. Drought resilient *Flemingia semialata* Roxb. for improving lac productivity in drought prone ecologies. Indian Journal of Genetics and Plant Breeding. 2017; 77(1):153-159.
6. Ghosh J, Lohot VD, Singhal V, Ghosal S, Sharma KK, Ramani R. Plant-insect-environment interaction for *kusmi* lac production in *ber* (*Ziziphus mauritiana*) varieties. The Ecoscan. 2014[a]; 6:407-411.
7. Tiwari AK, Shivhare AK. Pulses in India: retrospect and prospects. Govt. of India, Ministry of Agri. & Farmers Welfare (DAC&FW), Directorate of Pulses Development, Vindhyachal Bhavan, Bhopal, (M.P.), DPD, 2016 1(2).
8. Glover PM. Lac cultivation in India (2nd revised edition). Indian Lac Research Institute, Namkum, Ranchi, 1937, 8.
9. Shrama KK, Ramani R. Evaluation of *Arhar* (*Cajanus cajan*) varieties for intensive lac cultivation on plantation scale. Proceedings on National Symposium on Recent Advances in Beneficial Insects, 2013, 21.
10. Kumar P. Evaluation and improvement of *Arhar* for lac and pulse production, Annual report, ILRI, 1988, 35.
11. Ghosh J, Lohot VD, Singhal V, Ghosal S, Sharma KK. Pigeonpea-Lac insect interaction: Effect of lac culture on grain yield and biochemical parameters in pigeonpea. Indian Journal of Genetics and Plant Breeding. 2014[b]; 74(4):644-650.
12. Sharma KK, Bhattacharya A, Sushil SN. Indian lac insect, *Kerria lacca*, as an important source of honeydew. Bee World. 1999; 80(3):115-118.
13. Zhenghong Li, Saxena KB, Chaohong Z, Jianyum Z, Yong G, Xuxiao Z, *et al*. Pigeonpea an excellent host for lac production, International Chickpea and Pigeonpea Newsletter. 2001; 8:58-60.
14. McCready RM, Guggloz J, Silviera V, Owens HS. Determination of starch and amylose in vegetables. Analytical Chemistry. 1950; 22:1156-1158.
15. Nelson N. A photometric adaptation of the Somogyi method for the determination of glucose. The Journal of Biological Chemistry. 1944; 153:375-380.
16. Somogyi M. Notes on sugar determination. The Journal of Biological chemistry. 1952; 195:19-23.
17. Lowry OH, Rosebrough NJ, Farr AL, Randall RJ. Protein measurement with the Folin reagent. Journal of Biological Chemistry. 1952; 193:265-275.
18. Bray HG, Thorpe WV. Analysis of phenolic compounds of interest in metabolism. Methods of Biochemical Analysis. 1954; 1:27-52.
19. Scott TA, Melvin EH. Determination of dextran with anthrone. Analytical Chemistry. 1953; 25:1656-1661.
20. Pucher GW, Leavenworth CS, Vickery HB. Determination of starch in plant tissues. Analytical Chemistry. 1948; 20:850-583.
21. Malik YP, Bhagwan D. Impact of aphid (*Lipaphis erysimi*) intensity on plant growth and seed characters of Indian mustard. Indian Journal of Entomology. 1998; 60(1):36-42.
22. McCaffrey, Harmon BL, Davis JB, Brown AP, Erickson DA. Effect of late season insect infestation on yield, yield components and oil quality of *Brassica napus*, *B. rapa*, *B. juncea* and *Sinapis alba* in the Pacific Northwest region of the United States. The Journal of Agricultural Science. 1999; 132(3):281-288.
23. Kumar S, Singh YP, Singh SP, Singh R. Physical and biochemical aspects of host plant resistance to mustard aphid, *Lipaphis erysimi* (Kaltenbach) in rapeseed-mustard. Arthropod-Plant Interactions. 2017; 11(4):551-559.
24. Saxena BK, Kumar RV, Sultana R. Quality nutrition through pigeonpea-A review. Health. 2010; 2(11):1335-1344.
25. Mathew BA, Sule HA, Toluhi OJ, Idachaba SO, Ibrahim

AA, Abuh SJ. Studieson Protein Composition of Pigeon Pea [*CajanusCajan* (L.) Millspaugh] treated with Sodium Azide and Gamma Radiation. Journal of Pharmacy and Biological Sciences. 2015; 10(1):01-04.

26. Jaggal LG, Patil BR, Naik PM, Priya K. Genetic diversity of selected accessions for seed protein among pigeonpea minicore collection. Legume Research. 2016; 39(5):704-708.
27. Basky Z, Fónagy A. Glutenin and gliadin contents of flour derived from wheat infested with different aphid species. Pest Management Science. 2003; 59:426-430.
28. Singh P, Sinhal VK. Effect of aphid infestation on the biochemical constituents of mustard (*Brassica juncea*) plant. Journal of Phytology. 2011; 3(8):28-33.
29. Howe GA, Jander G. Plant Immunity to Insect Herbivores. Annual Review of Plant Biology. 2008; 59:41-66.
30. Mithofer A, Boland W. Plant defense against herbivores: chemical aspects. Annual Review of Plant Biology. 2012; 63:431-50.
31. Schultz JC, Appel HM, Ferrieri AP, Arnold TM. Flexible resource allocation during plant defense responses. Frontiers in Plant Science. 2013; (4):324.
32. Schuman MC, Baldwin IT. The Layers of Plant Responses to Insect Herbivores. Annual Review of Entomology. 2016; 61:373-94.
33. Ahn JH, Lee JS. Sugar acts as a regulatory signal on the wound inducible expression of SbHRGP3TGUS in transgenic plants. Plant Cell Reports. 2003; 22:286-293.
34. Schwachtje J, Baldwin IT. Why Does Herbivore Attack Reconfigure Primary Metabolism?. Plant Physiology. 2008; 146:845-851.
35. Chapin FS, Schulze ED, Mooney HA. The ecology and economics of storage in plants. Annual Review of Ecology and Systimatics. 1990; 21:423-447.
36. Würth MKR, Peláez-Riedl S, Wright SJ, Körner C. Non-structural carbohydrate pools in a tropical forest. Oecologia. 2005; 143:11-24.
37. Stam JM, Kroes A, Li Y, Gols R, Van Loon JJA, Poelman EH, Dicke M. Plant interactions with multiple insect herbivores: from community to genes. Annual Review of Plant Biology. 2014; 65:689-713.
38. Dicke M, Van Loon JJA, Soler R. Chemical complexity of volatiles from plants induced by multiple attacks. Nature Chemical Biology. 2009; 5(5):317-324.
39. Dubey NK, Goe R, Ranjan A, Idris A, Sing SK, Bag SK, *et al*. Comparative transcriptome analysis of *Gossypium hirsutum* L. in response to sap sucking insects: aphid and whitefly. BMC Genomics. 2013; 14:241-260.