Original Research Article **ISSN; 2411-1376**

Title: **Evaluation of intra and inter row spacing on the seed yield and yield component of Field pea (*Pisum sativum* L.)**

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Article Statistics

Received: 22nd June 2015

Revised: 14th Aug 2015

Accepted: 05th Sep 2015

***Key Words*:**

Field Pea, Intra Row Spacing, Inter Row Spacing

Abstract:

Among the high land legume crops, field pea is the second important stable food grain and it is important low-input break crops throughout the highlands of Ethiopia. The experiment on the effect of intra and inter-row spacing on filed pea was conducted for three year at Adet Agricultural research station and for one year at Debere tabor and Mota research station. Two inter-row spacing (20cm and 25cm) and three intra-row spacing's (5 cm, 10 cm and 15 cm) were evaluated using two released varieties (Sefinesh and Megeri) in factorial randomized complete block design with 3 replications. *The data was analyzed using SAS-JMP5 (2002) computer software.* Except the intra row spacing and the interaction effect between variety and intra row spacing, most the main and interaction effects were not significantly affect the agronomic attributes of both varieties. The highest and the lowest plant height for both varieties were recorded at the lowest and the highest intra row spacing, respectively. However, the highest seed yield and thousand seed weight were recorded when both varieties were planted at 10 cm intra row spacing. In the case of interaction effect between variety and intra row spacing, the highest seed yield was recorded when Megeri was planted at 10 cm intra row spacing but statistically on par with 5 cm and when Sefinesh was planted at 10 cm, 15 cm intra row spacing. However, both varieties gave the maximum seed yield when they were planted at 10 cm intra row spacing. On the other hand ,inter row spacing (20 cm and 25 cm) and the interaction effect between variety and inter row spacing did not gave significant yield difference. In conclusion, planting both varieties of field pea at 20 cm inter row spacing and 10 cm intra row spacing gave the optimum seed yield for both varieties in all experimental and similar areas. This study demonstrated that planting both field pea varieties at 20 cm/25cm inter and 10 cm intra row spacing significantly modify field pea yield and yield components by for exploiting the resources of the environment and gave a higher seed yield compared with the other plant spacing, suggesting that they could be used as management tools for increased yield in the high lands of the region. However, further separate research for each variety in different agro ecology of the region should be conducted to see the combined effect of more inter and intra row spacing.

Site this Article:

Yayeh Bitew, Fekremariam Asargew, Gobezie Chakelie**,** Evaluation of intra and inter row spacing on the seed yield and yield component of Field pea (*Pisum sativum* L.), *journal de afrikana*, 2015, 2(2); 1-15.

1. Introduction:

Grain legumes are important sources of significant amounts of proteins, carbohydrates, fiber, vitamins and some minerals. Grain legumes alone contribute to about 33% of the dietary protein nitrogen needs of humans. Moreover, it is also a good source of minerals (Kirmizi and Guleryuz, 2007). In general, cereals and legumes take a large place of human food consumption. Animal proteins being more expensive, especially people in developing countries depend largely on plant to fulfill their protein requirements. Proportionally legumes contain 20-25% protein, which is 2-3 times higher than the content in cereals. Therefore, they can be considered as a leading candidate for protein supply to poor areas of the world (Khalil, et al., 2006). Especially in areas where there is a pressing need for high energy and protein, their contribution is significant (Osman, 2007).

Among the grain legumes pea is an annual plant with slender, succulent stems, grown in cool temperate zones throughout the world (FAO, 2010). It has high levels of amino acids, lysine and tryptophan, which are relatively low in cereal grains. Moreover, Field pea contains approximately 21-25 % protein and high levels of carbohydrates, are low in fibber (Schatz and Endres, 2003).

Among the high land legume crops, field pea is the second important stable food grain in Ethiopia, mainly grown under rain fed conditions and consumed fresh or canned food, and also dried pea grains are used to make soup after broken in human died (Yayeh et al., 2014). It is important low-input break crops throughout the highlands of Ethiopia (1800-3000 m. a.sl) (Amare and Adamu, 1993). About 150 thousand hectare of land is allocated to field pea production every year putting Ethiopia in the list of major filed pea producing countries in the world (Beyene et al, 1988). The seed yield obtained by local farmers is quite low and variable. Thus, the national average yield of field pea is 12 qt/ha (CSA, 2012).

Among the many yield limiting factors in field pea production under farmers practice plant population and planting method are important. Appropriate plant density is a key for gainful production of field pea in various environments of Ethiopia. High yields are realized with optimum plant population and appropriate planting method. In the past some observations in plant population and planting methods were made at Holleta. The indications were 500,000plants/ha and row planting at 40 cm spacing were optimum (Beyene et al, 1988). However, it leads to lower canopy closure and

decreased the competitiveness of the crop against weeds, lower sunlight interception by the canopy (lower efficient use of water to reducing evaporation from the soil surface).

In Ethiopia due to lack of recommendations on inter and intra row spacing of field pea cultivars, plant populations on farmers' fields appear lower or higher than the optimum. Farmers traditionally either broadcast their seeds in isolation or mixed with Faba beans or as intercropping with other cereals and cover it with a local plow (Beyene et al, 1988). As a result very low yield is obtained. In addition to this seeds sown in broadcast seeding are distributed unevenly (which may result in overcrowding) and the method may not ensure that all seeds are sown at the correct depth. Furthermore, in field pea broadcast seeding makes difficulty to weeding and other intercultural practices. It is upon this background that this study sought to investigate the optimum Inter and Intra row spacing for field pea production in North Western Ethiopia.

2. Materials and methods

The experiment on the effect of intra and inter-row spacing on the two varieties of filed pea was conducted for three year (2012-2014) at Adet Agricultural research station. To confirm the two years result obtained at Adet, the research was conducted at Debere tabor and Mota research station for one year (2014). Global location, and the Chemical and physical properties of the soil data of the three research stations were explained by Mulugeta and Karl, (2010); and Habtamu et al., (2014) in Table 1. According to National Metrology Institute of Ethiopia, Bahir Bar branch (2015) , the mean monthly rain fall and temperature during the experimental years were explained in Figure 1. Although the amount is different, the mean monthly rain fall and temperature during the experimental years were similar trend in all experimental locations (Figure 1). The highest mean monthly rain fall were recorded in descending order at August (63-150 mm), July (65-130 mm), May (60-79mm) and September (50-75 mm). During the experimental years the highest (25-30^{0}C) and the lowest (19-24^{0}C) mean maximum temperature were recorded during the non experimental and experimental months (Figure 1). Three intra-row spacing's (5 cm, 10 cm and 15 cm) and two inter-row spacing (20 cm and 25 cm) were evaluated using two released varieties, Sefinesh and Megeri on a plot size of 5 m x 5m (25 m^2) in factorial randomized complete block design with 3 replications. The distance between each plot and replication were 0.5 m and 1m, respectively. At planting 100 kg/ha DAP were applied, planting date, weeding and other crop

management practices were applied as recommended for each site. All the relevant data's including plant height (cm), number of pods per plant, number of seeds per pod, seed, biomass yield (kg/ha) and thousand seed weight (gram), were collected from the net plot size and subjected to analysis of variance using SAS-JMP5 (2002) computer software. In all the comparisons, the level of significance was set at $\alpha = 0.05$. Mean comparison for the treatments were computed using Tukey HSD Test for parameters found to be significantly different at a given level of significant. Regression analysis with quadratic equation was performed between seed yield and intra row spacing to know the relationships between them. Moreover, simple liner regression with groups was also conducted to investigate the relationship between the combined effect of inter and intra row spacing and seed yield of field pea in the combined of three locations.

3. Result and discussion

The combined analysis of variance across the three location showed that the interaction effect between location and variety; location and inter row spacing; location and intra row spacing; and variety, inter and intra row spacing had no significant effect ($P>0.05$) on seed yield and on most yield component of field pea (Table 2). Hence, there is no need to analysis, discus and conclude the results on the effects of plant spacing for each specific location. However, the seed yield performance at each location was different. The average seed yield obtained was higher at Debere tabor research station (1999kg/ha), Motta research station (1846 kg/ha) and Adet research station (1846 kg/ha) in descending order (table 3). This is mainly due to high Available phosphors, total and soil organic matter in the respective locations as compared to other locations (Table 1). Yield responses to seeding rate varied among combinations of cultivars and sites (Johnston et al., 2002). The rain fall at the beginning to mid September and towards mid October caused some flower abortion and seed shattering, respectively (Figure 1)

3.1. Plant height (cm)

Plant height appeared to be highly significantly ($P<0.01$) affected due to differences in intra row spacing in combined of three location as indicated in Table 2. The highest mean plant height was recorded at 5 cm intra row spacing (137.27 cm) but statistically on par with 10 cm intra row spacing (134.05 cm), while the lowest was recorded at 15 cm intra row spacing (124.40 cm) (Table 3) probably because of the presence of intra-specific competition particularly struggle for light in the former plant spacing and absence of intra-specific

competition in the wider plant spacing in the latter plant spacing. Similarly, the analysis of variance showed that the interaction effect between varieties and intra row spacing significantly ($P<0.05$) affect the plant height (Table 2). The highest mean plant height was recorded when Sefineshe was planted at 5 cm intra row spacing (150.90 cm) but statistically non significant when planted at 10 cm (149.29 cm), while the lowest was recorded when Megeri was planted at 15 cm intra row spacing (112.82 cm) (Table 3). However, when we saw both varieties separately the highest and the lowest mean plant height were recorded when field pea was planted at the narrow and the wider intra row spacing (Table 3), respectively probably due to competition of plants in higher densities on light, resulting in taller plants. Similar results were obtained by Derya Ozveren Yucel, (2013); Inanç and Yıldırım (2007), who found that plant height increases as planting density increases from 300000 plants/ha to 500000plants/ha. The analysis of variance also indicated that plant height was significantly ($P<0.05$) affected by variety; inter row spacing; interaction effect between varieties and inter row spacing and interaction effect between varieties, inter row spacing and intra row spacing (Table 2). Yayeh et al., (2014) also stated that most the main and the interaction effects used in this experiment were significantly affect the plant height.

3.2. Number of pods per plant and seeds per pod

The combined analysis of variance across the three location indicated that number of pods per plant and seeds per pod had not significantly ($P>0.05$) affected by intra row spacing, interaction effect between variety and intra row spacing and other most treatments (Table 2). Number of pods per plant and seeds per pod for both varieties were not significantly respond to inter and intra row spacing (Table 1 and 2). Moreover, number of pods per plant and seeds per pod were relatively constant across plant spacing. (Table 3). Similarly, Yayeh et al., (2014) demonstrated that combined analysis of variance showed that both the main and the interaction effect did not significantly affect ($P>0.05$) the number of pods per plant. However, Derya Ozveren Yucel, (2013) showed 400000 plant/ha of plant density gave the highest value of total pod number followed by 300000 plant/ha of plant density, whereas the lowest value was obtained from 500000 plant/ha of plant density.

3.3. Seed yield

The combined analysis of variance across location indicated seed yield of field pea was significantly ($P<0.01$) affected by intra row

spacing and interaction effect between variety and intra row spacing (Table 2). The highest and the lowest mean seed yield were recorded when field pea was planted at 10 cm (1745.24 kg/ha) and 15 cm (1413.80 kg/ha) intra row spacing, respectively (Table 3).This is due to as soil moisture increases or as weed competition increases, yields may not be maximized at these thinner stands (20cmx15cm and 25x15cm=333,333-266,666). In contrary, at the other end of the range, crop stands of greater than- recommended density may increase the risk of foliar disease infection (Nybo, 2005). Field pea seed yield increased and weed numbers reduced with increasing seed rate to a rate between 500000 and 1000000 seeds/ha (Townley-Smith and Wright (1994). In the case of interaction effect between variety and intra row spacing, the highest mean seed yield was recorded when Megeri was planted at 10 cm intra row spacing (1785.41 kg/ha) but statistically on par with 5 cm (1608.08 kg/ha) and when Sefinesh was planted at 10 cm (1705.06 kg/ha) and 15 cm (1692.07 kg/ha) intra row spacing (Table 2). However, both varieties gave the maximum seed yield when they are planted at 10 cm intra row spacing (1705-1785.41 kg/ha) (Table 3). Though, both the main effect and the interaction effect had statistically similar effect on number of pods per plant and seeds per pod, higher number of pods per plant and seeds per pod at 10 cm intra row spacing attributes to the highest mean seed yield of field pea varieties. On the other hand, Greater inter-plant competition, as plant density increased at 5 cm intra row spacing, would explain the corresponding increase in seedling mortality and associated stand loss (Johnston et al., 2002). Maximum seed yield was achieved at around 80-100 plants/m2 and 60-80 plants/m2 at the areas of high and less rain fall, respectively (Ukrainetz, 1990; Lafond et al., 1997; Larn McMurray, 2003)

Variety, Inter row spacing, interaction effect between varieties and inter row spacing, interaction effect between inter and intra row spacing and interaction effect between varieties, inter and intra row spacing had no significant effect on mean seed yield of field pea (Table 2). Inter row spacing in general has little impact on pea as compared to intra row spacing because of the crop's ability to develop additional basal branches (Nybo, 2005). However, Nybo, (2005) and Cutforth and Selles (1992) explained narrower row spacing will result in faster canopy closure and reduced soil moisture loss through evaporation between the rows. Moreover, the same author also stated that narrower row spacing encourages quicker rooting exploitation of the soil between the rows and subsequent use of mid-row soil moisture.

On the other hand wider row spacing can be used in high moisture regions to reduce the risk of a thick crop canopy, leading to poor pod set and lodging. Wider row spacing may also reduce disease pressure if the micro-climate within the crop is kept drier due to the wider spacing. Increasing stand density (seed rate) reduced weed numbers and in turn increasing seed yield of field pea (Townley'Smith and Wright, 1993). However, the present study is in contrary to the finding of Nleya and John, (2011), who stated that pea plants compensated for low plant populations by producing more pods per plant and more seeds per pod.

The response of mean seed yield could be explained by quadratic equations. Increasing the intra row spacing revealed a peak seed yield at approximately 10 cm (400,000-500,000 plants/ha) for both varieties (Figure 2). As intra row spacing increased from 5 cm to 10 cm at the given inter row spacing, seed yield of pea increased by 12.15% in the combined of the three locations. The reduction can be confounded by intense inter-plant competition among the closely spaced plants associated with low intra row spacing/high seeding rates/ which lead to plant die-off. Although, further increases in intra row spacing did not result in additional input cost, but increasing intra row spacing from 10 cm to 15 cm did result in reduction of seed yield by19%. These results are in agree with results of Gan *et al*. (2003), Derya Ozveren Yucel, (2013) and Yayeh et al., (2014), who reported that the seed yield of dry pea increased with increasing plant population (decreasing row spacing). Faba bean was more responsive and average yield increased up to the highest density, whereas yields of field pea plateau above 400000-450000 plants/ha (Armstrong et al., 2008).

Although, the interaction effect between variety, inter and intra row spacing had no significant effect on mean seed yield of field pea, the regression analysis with groups showed that Increases intra and inter row spacing together for Megeri (Variety 2) (reduction in plant density) result in yield penalty and it is similar to the previous findings of Ozveren, (2013) (Figure 3). However, Increases intra and inter row spacing together for Sefineshe (variety1) resulted in seed yield increment and it is similar to the findings of Türk et al., (2011) (Figure 3). The later result was also supported by Hedley and Ambrose (1981), who found that low plant densities can be compensated by substantial branching. The same experiment was conducted for two years at Adet research farm and similar findings were obtained (Yayeh et al., 2014). However, this is contrary to the results the main effects of this experiment and the findings of

Yayeh et al., (2014), who found that the seed yield and thousand seed weight of both the tested varieties are not significantly different in all location and years. This result makes confusion and needs separate research on effect of more inter and intra row spacing on each varieties in different agro ecologies of the country.

3.4. Biomass yield

Intra row spacing highly significantly affect the biomass yield (Table 2). The highest biomass yield was recorded at 5 cm intra row spacing (5047.40 kg/ha) but on par with 10cm intra row spacing (4750.67 kg/ha), while the lowest was recorded at 15 cm intra row spacing (3813.8 kg/ha). Biomass yield had also significantly affected by interaction effect between variety and intra row spacing (Table 2). The highest biomass yield was recorded when Sefineshe was planted at 5cm intra row spacing (5912.16 kg/ha), while the lowest was recorded when Megeri was planted at 15 cm intra row spacing (2606.70 kg/ha). However, increasing intra row spacing causes reduction in plant height and biomass yield of both field pea varieties (Table 3). High biomass yield at narrow intra row spacing might be due to highest plant density due to narrow intra row spacing. Increased in plant height of field pea in line with plant population (narrowing intra row spacing) might be also contributed to increase in biomass yield. Like plant height, biomass yield had significantly affected by variety, interaction effect between varieties and inter row spacing and interaction effect between varieties, inter and intra row spacing (Table 2).

3.5. Thousand Seed weight

Thousand Seed weight was only significantly affected by intra row spacing (Table 2). Similarly the research conducted at Adet Research farm by Yayeh et al., (2014) showed that thousand seed weight had not significantly affected by intra and inter row spacing; and there was no difference in thousand seed weight between both field pea varieties. The highest mean Thousand Seed weight was recorded at 15 cm intra row spacing (145.77 gram) but statistically non significant with 10 cm intra row spacing (144.17 gram), while the lowest mean thousand seed weight was recorded at the narrow intra row spacing (5cm) (136.94 gram) (Table 3). These results agree with Johnston et al., (2002)) who found that yield component compensation occurred where increased plant density from higher seeding rates reduced seed weight. This could be due to higher intra-specific competition in the narrow intra row spacing causes reduction of assimilates might have resulted to poor seed filling of field pea. The highest Thousand Seed weight of field pea

in wider intra row spacing could be due to large seed size in a very low plant population which could be attributed to large accumulation of assimilate. The analysis of variance showed that there was no significant difference on Thousand Seed weight among the varieties. The analysis of variance indicated that Variety, Inter row spacing, interaction effect between varieties and inter row spacing, interaction effect between inter and intra row spacing and interaction effect between varieties, inter and intra row spacing had no significant effect on Thousand Seed weight (Table 2).

4. Conclusion and recommendation:

Except the intra row spacing and the interaction effect between variety and intra row spacing, most of the main and interaction effects were not significantly affect the agronomic attributes of both field pea cultivars. The highest and the lowest plant height for both varieties were recorded at the lowest and the highest intra row spacing, respectively. However, the highest seed yield and thousand seed weight were recorded when both varieties were planted at 10 cm intra row spacing. On the other hand, inter row spacing of 20 cm and 25 cm and the interaction effect between variety and inter row spacing did not gave significant yield differences. In conclusion, planting both varieties of field pea from 20 cm inter row spacing and 10 cm intra row spacing gave the optimum seed yield for both varieties in all experimental and similar areas. This study demonstrated that these factors significantly modify field pea yield and yield components, suggesting that they could be used as management tools for increased yield in the high lands of the region. However, further separate researches for each variety in different agro ecology of the region should be conducted to see the combined effect of more inter and intra row spacing.

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List of Tables and Figures:

Location	latitude	longitude	Altitude (mas)	Available P.(PPm)	Total N	SOM (%)	Soil type
Adet	110 17'N	370 43'E	2240	1.688	0.095	1.898	Nitosol
Mota	110 5'N	370 52'E	2487	na	na		Nitosol
D/tabore	110 51'N	380 1'E	2706	15.02	0.21	3.69	Nitosol

Note: na- data not available

Table 1. Global location, average weather; and the Chemical and physical properties of the soil data of the three research stations

Source	DF	Prob > F					
		PH	NPPP	NSPP	SY	BY	TSW
V	1	<.0001	0.0497	0.0001	0.2007	<.0001	0.1041
SP	2	0.0045	0.1378	0.3055	0.0072	0.0018	0.0055
SR	1	0.0476	0.0251	0.3448	0.4187	0.7758	0.3050
LO	2	<.0001	0.5857	0.0002	<.0001	0.7005	0.0124
V*SP	2	0.04577	0.9991	0.1718	0.0015	0.0367	0.3564
V*SR	1	0.03616	0.5612	0.0929	0.6945	0.4325	0.0457
V*LO	2	0.6993	1.0000	0.7195	0.3859	0.0196	0.9907
SP*SR	2	0.8766	0.4598	0.3889	0.1803	0.5925	0.0173
SP*LO	4	0.9840	0.6628	0.8811	0.1896	0.7380	0.7483
SR*LO	2	0.3139	0.4179	0.4968	0.8214	0.6588	0.8388
V*SP*SR	2	0.03767	0.2920	0.2240	0.0688	0.0450	0.6289
V*SP*LO	4	0.7912	0.9902	0.6062	0.8187	0.2102	0.7627
V*SR*LO	2	1.0000	0.9759	0.9922	0.7068	0.6189	0.4714
SP*SR*LO	4	0.7902	0.8235	0.9058	0.7709	0.5573	0.3203
V*SP*SR*LO	4	0.9575	0.7562	0.9553	0.5537	0.4149	0.7649

Note: *On the above Table (2) PH , NPPP , NSPP, SY , BY and TSW refers to plant height in cm, number of pods per plant, number of seeds per pod, seed yield in kilogram/ha and Thousand seed weight in gram, respectively*

Table 2: Combined Analysis of variance across location for seed yield of field pea as affected by plant spacing

Treatment and statistics	Mean of agronomic attributes					
	PH	NPPP	NSPP	GY	BY	TSW
Intra row spacing						
5 cm	137.27a	7.76	4.61	1533.13ab	5047.40a	136.944b
10 cm	134.05a	8.83	4.92	1745.24a	4750.67a	144.167a
15 cm	124.40b	8.68	4.85	1413.80b	3813.81b	145.778a
Mean	131.91	8.42	4.79	1564.01	4537.29	142.29
LSD (%)	**	NS	NS	**	**	*
Interaction effect of variety and intra row spacing						
Sefinesh@5 cm	150.90a	8.23	4.48	1458.18ab	5912.16a	137.44
Sefinesh@10 cm	149.29a	9.31	4.41	1705.06a	5441.48ab	145.11
Sefinesh*@15 cm	135.98ab	9.13	4.46	1692.07a	5020.91ab	150.00
Megeri@5 cm	123.65bc	7.29	4.75	1608.08a	4182.63b	136.44
Megeri@10 cm	118.81c	8.36	5.43	1785.41a	4059.86b	143.22
Megeri@15 cm	112.82c	8.22	5.23	1135.52b	2606.70c	141.55
Mean	128.11	8.46	4.86	1585.23	4262.32	143.26
LSD (%)	*	NS	NS	**	*	NS
Interaction effect of variety, inter and intra row spacing						
Mean	131.91	8.424	4.79	1564.05	4537.28	142.29
LSD (5%)	*	NS	NS	NS	*	NS
CV (%)	12.2	28.5	16.6	27.9	25.7	7.7

***Note**: Means followed by different letters in columns are significantly different at 5 % of probability level according to Tukey HSD Test. On the above table PH , NPPP , NSPP,, SY , BY and TSW refers to plant height in cm, number of pods per plant, number of seeds per pod, seed yield in kilogram/ha and Thousand seed weigh in gram, respectively*

Table 3: Maine and interaction effect on mean seed yield of field pea Combined across all locations

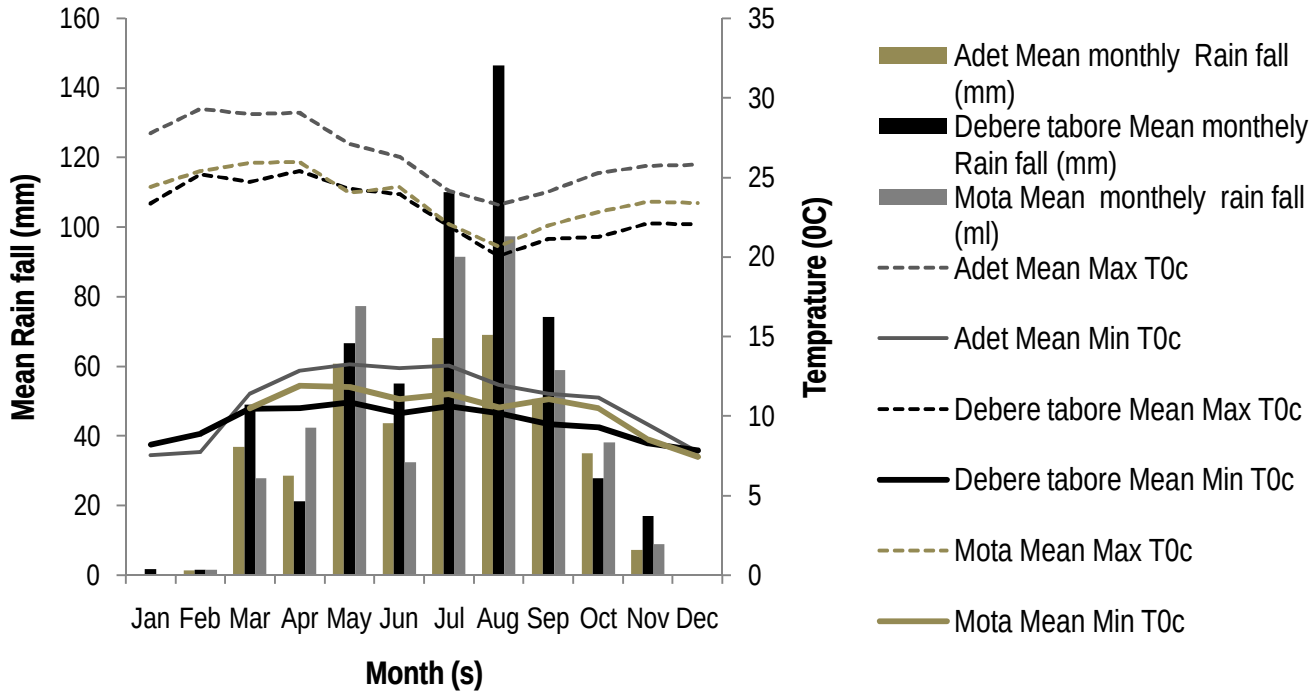

Figure 1: Mean Monthly Rain fall (mm) and mean temperature (0C) at all research areas in 2014 cropping season

Seed Yield (kg/ha) $=-10.87x^2-11.93x+1864.57$

$R^2=0.044$

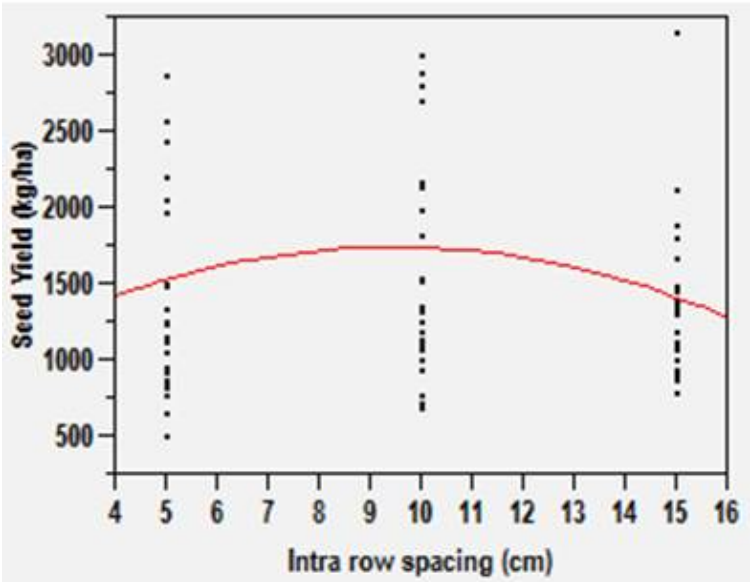

Figure 2. Relationship between intra row spacing and seed yield in combined of the three location.

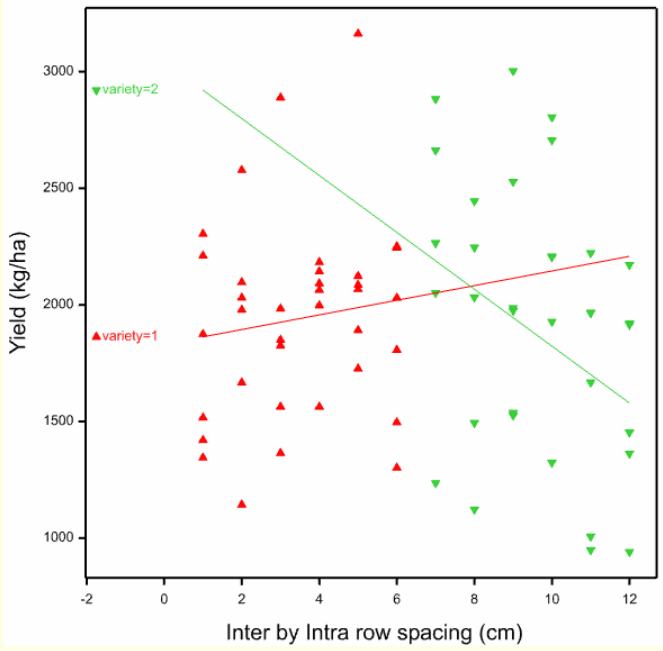

Figure 3: Simple liner regressions with groups showing the relationship between the combined effect of inter and intra row spacing and seed yield of field pea varieties in the combined of three location