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Influence of capsule position on seed traits and oil content of linseed (*Linum usitatissimum* L.)

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Abstract

Seed traits (Seeds per capsule, thousand seed weight and Seeds-husk ratio) and oil content were influenced by prevailing environmental conditions during maturity and post flowering period. A study was executed to document the influence of capsule position on seed traits and oil contents of linseed. The seeds of linseed (*Linum usitatissimum* L.) cultivar L-6 were sown during month of October, 2009. Prior to appearance of flowers at terminal node, 300 plants were selected (100 plants in each replication) in three replications. On the appearance of first capsule on terminal node labeling to take capsule samples from different positions of plant was done on the day of emergence. The treatments were twelve (Label-1 to Label-12) and it was based on the appearance of capsules on different dates. Capsules labelled on each position were harvested and thrashed separately. Seed traits like seed per capsule, thousand seed weight, seed-husk ratio and oil content were recorded from harvested capsules separately. The maximum seed per capsule (9.05) was recorded for the first label and it decreased significantly for the last label (6.01).This might be due to strong relationship between first sink with source compared to last where plant might requires more ATP to build source-sink relationship. Similar results were obtained for thousand seed weight, seed-husk ratio and oil accumulation. Therefore, it can be concluded that capsule position has significant effect on seed traits and oil contents of linseed that could be due to differential partitioning of photoassimilate at different points of capsule. In addition consistent decrease in values of above parameters may have been caused due to weaker source-sink link and competition for assimilates.

Keywords: capsule position, linseed, photosynthates, physiochemical characteristics.
Abbreviations: ATP- Adenosine Triphosphate; AOAC- Association of Official Analytical Chemists; PMAS- Pir Mehr Ali Shah; TSW-Thousand seed weight.

Introduction

Linseed or Oilseed flax (Linum usitatissimum L.) belongs to family Linaceae comprising of nine genera and ~150 species (Tadesse et al., 2009). According to a new classification it consists of 22 genera with ~300 species (Vromans, 2006). It is the only economic species under Linaceae that is agronomically important. It is the sixth largest oilseed crop in the world and is one of the oldest known cultivated plant species (Bhatty and Rowland, 1990). Linseed is a cool temperate annual herb with erect, cylindrical stems, 20-100 cm tall. Being a cool season crop, fall air temperatures under 10 °C possibly inhibit growth rate subsequently delaying the flowering process (Gusta et al., 1997). Linseed as an oilseed is crop grown many parts of world and has wide adaptability (FAOSTAT, 2012). It is an important source of fatty acids for human diet and health (Millis, 2002). Linseed also has the potential to be used as food, fuel and fiber. However, the limiting factor which affects its adaptability is the great variability of seed yield (Weiss, 2000). Thus, understanding of the factors that can affect seed traits and oil contents is of prime importance. The principal stem axis and the corresponding lateral branches exhibit narrow multi-branched floral arrangement (Millam et al., 2005). The inflorescence was reported as corymbose raceme type bearing blue/white flowers at the tip of the branches (Gill, 1987; Millam et al., 2005). Flowers are mostly self-pollinated. A considerable rate of cross pollination was reported in certain cultivars (Gill, 1987). The fruit is a capsule, containing ~10 shiny, flat seeds of different colors. Flowering starts following 60-75 days of sowing. Flowers bloom in clusters, petals open up at down and are usually shed by early afternoon time period. Hence floral blooms occur only for a few hours. In its natural environment linseed is pollinated during morning hours. The petals dropped off after 4-5 h of blossoming (Cullis, 2007).

The mature fruit of the linseed is a capsule (dry boll). The bolls are reported to start maturing within 20-25 days following flowering. Individual capsule has five distinct chambers segmented by a wall/septum. The capsules were reported to produce around 10 seed in case of complete maturity, but in most cases lower number of seeds/capsule was observed under field conditions (Cullis, 2007). During the development of capsule dry weight increases consistently and touches the peak at maturity. Seed weight was influenced by prevailing environmental conditions during post flowering period (Berti et al., 2007). The most active period of oil

Table 1. Mean temperature and total Precipitation during growing season.

Months	Mean Temperature (˚C)	Precipitation (mm)
October	23.1	Trace
November	16.4	16
December	12.4	0
January	12	18
February	13.6	80
March	14.3	115.5
April	26	49.7
May	29.4	22.6

Source: Meteorological Office, Rawalpindi.

Table 2. Effect of capsule position on Seed traits and oil content of Linseed.

Capsule Position	Seed/capsule	TSW (g)	Seed-husk ratio	Oil content (%)
1	9.05A	6.15A	1.56A	36.29A
2	8.77B	6.05AB	1.54AB	35.47B
3	8.52C	5.97BC	1.50ABC	34.64C
4	8.08D	5.88CD	1.48BCD	34.61C
5	7.82E	5.84D	1.43CDE	34.40B
6	7.53F	5.79DE	1.41DEF	33.70D
7	7.29G	5.68EF	1.39EFG	33.26DE
8	7.06H	5.61 FG	1.37EFG	33.18DE
9	6.84I	5.51 GH	1.35FG	32.71EF
10	6.54J	5.42 HI	1.31GH	32.61F
11	6.24K	5.34 IJ	1.26HI	31.86G
12	6.01L	5.29 J	1.22I	31.15 FG

Different letters with means in the same column show a significant difference at $P < 0.05$).

accumulation occurs during early developmental stages of capsule (Herchi et al., 2009). The growth of capsule or seed depends upon photosynthetic activities of leaves and inflorescences and translocation of photoassimilate in the plant canopy before flowering (Dordas, 2009; Blum, 1998). Drymatter accumulation in plants prior to flowering is an important source of photosynthetic products and essential for seed growth and development (Dordas, 2009). The relationship between source and sink might be dropped under hot and dry conditions resulting to significant decline in crop yield (Blum, 1998).Therefore, active mobilization of drymatter to seed is essential for healthy seed growth and it might depends upon genotype, environment, capsule position, planting date, nutrients and water stress. Seed formation and development takes place at different times, different positions (distance from main stem photosynthates producing region) and at different temperature, thus physical and chemical characteristics are affected differently. Thus, presumably difference of time, distance of sink from source and temperature prevailing during post flowering period affect physicochemical characteristics of seed. At the start of flowering maximum leaf area in synthesizing ample quantity of photo assimilates which is transported to the sink. However, towards the end of flowering total leaf area decreases with yellowing of lower leaves while at the same time demand by sink increases creating competition of assimilate partitioning. Information related to influence of capsule's position on the seed traits and oil contents of linseed is scarce. Thus present study was contemplated with the objective to record the influence of capsule position on the seed traits and oil contents of linseed.

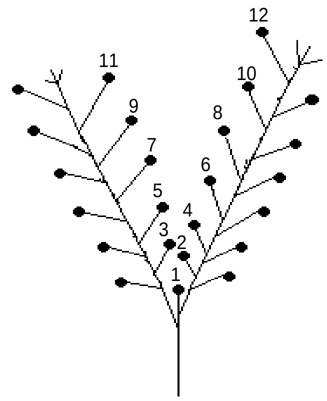

Fig 1. Linseed plant labelling based upon emergence of nodes for sampling of capsules.

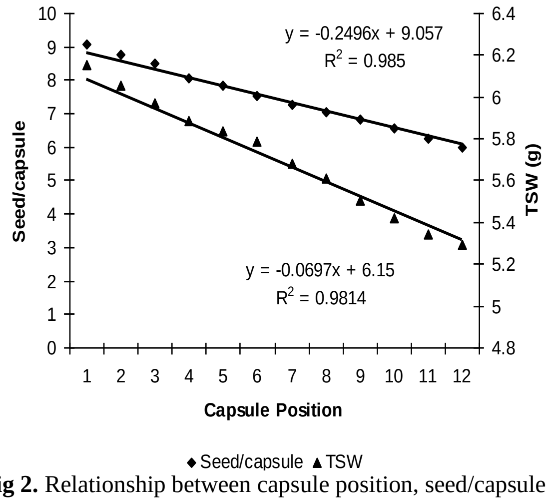

Fig 2. Relationship between capsule position, seed/capsule and TSW of linseed.

Results and Discussion

Effect of capsule position on seeds per capsule

The position of capsule affected seeds per capsule significantly (P <0.05) (Table 2). The maximum (9.057)

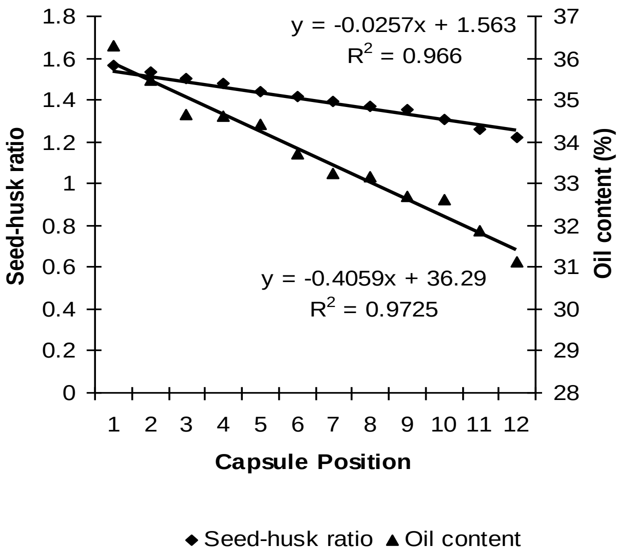

Fig 3. Relationship between capsule position, seed-husk ratio and oil content of linseed oil.

number of seed/capsule was noted at the lowest position those decreased progressively towards the top. The minimum (6.01) number of seeds per capsule was observed at top position, thus exhibited a reduction of 34 % for seeds per capsule between lowest and top most position. The maximum number of seeds per capsule at lowest position capsule indicated that conditions at the time of first capsule formation and development were more favorable *i.e.* temperature and maximum availability of photosynthates as most of the leaves were green having maximum photosynthetic capacity. Gupta et al. (2009) reported that temperature directs the relation between source and sink which subsequently controls the assimilate availability essential for filling of the seeds. Progressive reduction in number of seeds/ capsule might be the effect of temperature variation. The difference in mean temperature from start to the end of capsule formation may have caused decrease in seeds per capsule. Results of present study were similar to Gunasekera *et al.* (2006); who observed significant decrease in seed setting through increase of temperature in rapeseed. Similarly, drymatter accumulation and its partitioning into different plant parts are significantly affected by growing season. The highest capsule number might be due to climatic conditions during its filling period that ultimately have significant effect on seed yield as reported by Blum (1998). The importance of number of capsules as determinant factor of crop yield was reported in earlier research and they concluded that capsule numbers needs to consider as an important yield limiting factor (Copur et al., 2006).

Effect of Capsule position on thousand seed weight

The thousand seed weight (TSW) from different capsule position differed significantly ($P < 0.05$) (Table 2). Seeds at lower capsule position had maximum (6.15 g) TSW which decreased to minimum at the top (5.29 g), thus showed reduction of 17 % in TSW between upper most and lowest capsule positions. These variations in seed weight might be due to lesser availability of photo-assimilate and climatic factor like temperature during flowering. High temperature during reproductive stage significantly inhibited the import of photosynthates and thereby decreased the sink strength. Reduced availability of photosynthate and late maturation of seeds of upper capsule as compared to lower capsule may have caused the decrease. Similar observations were recorded by Munshai and Kumari, (2006) who found healthier seed from lower siliquas than seeds from upper siliquas in rapeseed. Similarly, variability in seed weight throughout seed development in different whorls of sunflower head was recorded by Gupta *et al.* (2009), while Kaleem and Hassan, (2010) observed heavier seeds in outer circles of sunflower than in inner circle. Similarly, Khan *et al.* (2011) concluded that in soybean high temperature stress during flowering and pod development had larger effect on seed set and seed filling duration. Thus, irrespective of crop, phenomena of assimilate transportation seems to be the same *i.e*., longer the distance from source lesser is accumulation in sink. Inverse relationship between capsule position (Fig. 2), seed per capsule and thousand seed weight was supportive to above assumption.

Effect of Capsule position on seed-husk ratio

The seed-husk ratio (Table 2) showed significant differences among different capsule position located at upper and lower part of the plant. Seed-husk ratio varied considerably from the lower capsules to upper capsule position. However, maximum (1.56 %) seed husk ratio was observed at lowest position and minimum (1.22 %) at top most position. The difference in seed to husk ratio between upper and lower part might be due to the fact that the seeds present in the lower part capsules received more photo-assimilates as compared to the upper parts. In sesame, plant the difference in the hull percentage between the seeds from the upper and lower part capsules was due to the less availability of photo-assimilates to the upper part capsules (Tashiro et al., 1990), hence results of present study are in line.

Effect of Capsule position on oil content

Oil content of the seeds exhibited significant variation for different capsule position (Table 2). The maximum oil content (36.2 %) were recorded from capsules located at the bottom part of the plant and those with the minimum oil content (31.1 %) from capsules located at the upper part of the plant. A variation of 15% oil content was apparent between the lowest and the top most capsule position. The differences in climatic conditions during seed development/maturation and uneven ripening of individual capsules might have caused variations in oil content. Our results were in agreement with Munshi and Kochhar (2006; 2008); those observed variation in pattern of oil filing in mustard seeds from basal to apical positions due to the variable environmental conditions. A similar pattern of variability between various nodal positions of soybean stem axis was recorded by Guleria et al. (2007).

Materials and methods

Study site

Influence of capsule position on physicochemical characteristics of linseed was studied through field experiment conducted at PMAS Arid Agriculture University, Rawalpindi, Pakistan during 2009-10. The land was disked and ploughed twice before planting. Recommended doses of nitrogen, phosphorus and potassium was applied at the time of last ploughing. Seeds of linseed variety L-6 were used as test material. Seeds were sown with the help of hand drill in plot size of 6 x 3 meters on October, 25 2009. The distance between rows were maintained at 20 cm and between plants at 5-6 cm after thinning at 3-4 leaves stage. 300 plants were randomly selected before initiation of flowering.

Plant labelling

On the appearance of capsule on main stem labelling was done on the day of emergence, starting from lowest point. The first labelling was recorded as first treatment, which initiated on March 22, 2010. Similarly, 12 treatments were recorded on 12 different dates on the basis of emergence of capsules. On each date ~100 capsules were labelled. Labelling continued till the end of flowering on main capsule bearing the raceme. The capsule appearance ended on April, 27. A schematic diagram of labelled capsules has been presented as Fig. 1. Thus, the experiment had 12 treatments and three replications with 100 plants in each replication arranged in completely randomized design. All the plants with labelled capsules were harvested at maturity.

Seed traits and oil content

All the labelled capsules with respective dates were removed and kept separately. These labelled capsules were thrashed manually and total number of seeds/capsule counted and weighed separately. Seeds per capsule, thousand seed weight and seed-husk ratios were calculated at maturity. Seed from each position were separately analysed for oil. Oil content was done by Soxhelet apparatus using AOAC (1990) protcol.

Statistical analysis

Data were analyzed using the Mstat-C version 2.1 (Freed and Eisensmith, 1986). Duncan's multiple range test was applied to compare the means at $P = 0.05$ **(**Montgomery**,** 2001). Weather data was obtained from Regional Meteorological Centre located near the experimental site (Table 1).

Conclusion

It can be concluded from present results that the seeds developed in capsule at lower position having lesser distance from ground and source was more productive in terms of various seed traits and oil content in comparison to those developed at upper capsule positions. Therefore, it is important to develop/breed such cultivars having some definite flowering pattern along with maximum flowers at lower positions and lesser distance from source.

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