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# Morphometric and Qualitative Response of Onion Varieties in Poplar-vegetable Based Agroforestry System

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**ABSTRACT**

*Vegetable-based agroforestry has prompted deep interest, considering the dietary, economic, and multifarious utility of onion (Allium cepa L.) which is an important vegetable crop; the present study was conducted at Punjab Agricultural University, Ludhiana, India for two years, 2018-19 and 2019-20 under split-split plot design. The six onion varieties (POH-1, PRO-6, PRO-7, PWO-2, PYO-1 and Punjab Naroya) were planted in two environments (poplar and open) at three planting times (mid-December, end-December and mid-January). The morphological and qualitative performance of onion varied significantly with transplanting time and amongst the varieties. With the advancement of planting time, the height no. of leaves and neck thickness showed a declining trend. The mid-December planted seedlings, shown taller plants (64.69 and 65.18 cm) with maximum leaves (7.41 and 6.08) and neck thickness (1.25 cm and 1.56 cm) followed by end December. Among the six onion varieties, PRO-7 was significantly taller (65.71cm and 61.37cm) with maximum no. of leaves (7.28 and 6.16) and took minimum number of days to bulb initiation (68) and maturity (122). PYO-1 recorded significantly more neck thickness than other varieties but at par with Pb. Naroya. Nevertheless, PWO-2 produced significantly higher mean dry matter content (15.14%) as well as total soluble solids, (13.11%) thus better variety in quality in both the years. Conversely, the variety PYO-1 performed poorly both in terms of growth and quality (DMC-9.8% and TSS- 10.02%) indicating it may not be the most suitable choice for cultivation under poplar. The mean performance of the three planting times showed that maximum DMC was produced in mid-December planted crop and decreased towards mid-January planting time while TSS remained insignificant for transplanting times. Henceforth, variety PWO-2 performed better with poplar for nutritional value while variety PRO-7 has proved better in terms of substantial growth rate.*

## INTRODUCTION

Progressive farmers in Punjab state are exploring other viable options for diversifying the traditional rice-wheat crop rotation farming system. Due to overutilization of land resources that caused lowering of water table and nutrient reserves, the productivity levels have declined and distressed the farming communities. Agroforestry has proved a boon to agrarian farmers in terms of ecological resilience and economic stability. Short-rotation woody perennials, mainly poplar and eucalyptus have revolutionized agroforestry sector in the north-western part of the country. A number of cereals, vegetables, and other food crops have been tried with one of the fastest growing industrial woody species poplars (*Populus deltoides).* In present scenario, vegetable-based agroforestry has prompted deep interest among scientists to look for vegetable's compatibility with tree crops as they have good nutritional value and fetch higher monetary value in the

market. Onion is one such important vegetable and spice crop which is being used in food and also has multiple medicinal properties. Despite its geo-climatic seasonal cultivation, it has a market demand throughout the year. The harvests of *rabi* exports crop are mainly kept for storage and used for domestic markets and export, from May to October. There lies a critical supply gap from November to January because of exhausted stored stock that results to prices shoot up in North India (Sharma *et al.,* 2020). Punjab, being the agrarian state has very less area under onion cultivation. So, there is wide scope for onion cultivation in the fertile alluvial farming lands to fulfill supply and demand gap. In the context of agroforestry, the poplar species being planted in wider scale offers the compatibility to *rabi* onion cultivation during winter season due to its deciduous nature. Also, due to congenial climatic conditions for *rabi* season onion cultivation in North India, growth and development of onion bulbs are good and therefore give higher quality and yield productions. The Vegetable Science Department of Punjab Agricultural University has developed superior cultivars of onion with higher yield potentials to enhance farmers income. The performance of superior genotypes depends upon genotype and environmental interactions (Kimani *et al.,* 1993). In consideration to environments, agroforestry practice has its own relevance where tree modulates the microenvironment and therefore influence the crop in the understory at tree-crop interface which is responsible for differential quantitative and qualitative production potential as compared to tree less or pure agricultural lands. Also, crop variety responds differently to planting date, therefore planting time assumes utmost importance in causing array of morpho-anatomical, physiological, and biochemical changes in plants that alters growth and development (Shrestha *et al.,* 2018). Although superior high yielding varieties are evolved coupled with better quality parameters, but some studies (Chattopadhyay *et al.,* 2013) recorded weak or negative association of quality traits with onion bulb yield, while morphometric attributes like plant height, marketable bulb weight are found to have direct and positive effect on bulb yield. The neck thickness is given importance as it determines the storage potential with lesser size restricting the entry point for pathogens, responsible for post-harvest loss (Maw and Mullinix, 2005). The dry matter content (DMC) value is very much important for dehydration. It is believed that DMC and TSS, influence long storage period in onion (Mahanthesh *et al.*, 2008). Therefore, considering the valuable factors of onion production, the present study was conducted to overview the patterns of growth and quality.

## MATERIALS AND METHODS

### *Experimental site conditions*

The experimental site falls in the "Trans-Gangetic plains region" agroclimatic zone of Punjab and located at 30̊ 58' N latitude, 75̊ 45' E longitude and 247 m above the mean sea level. The site experiences considerable variation in temperature with the maximum temperature goes up to 45℃ in summers and minimum to 4℃ in winters. The soil analysis revealed the loamy sand texture of the soil with normal EC, alkaline pH, low organic carbon and available nitrogen and medium in available potassium and phosphorus (Bhardwaj *et al.,* 2021).

### *Experimental Design and Layout*

The research experiment was carried out consecutively for two years (2018-19, 2019-20) in the research area of Department of Forestry and Natural Resources, PAU, Ludhiana. The age of the poplar (*Populus deltoiedes*) plantation during intercropping trial was 4 and 5 years. The effect of phenological event of leafing was evaluated by noticing changes in leaf fall pattern and leaf area index (LAI) over the study period which is known to cause microenvironmental amelioration (Plate:2). The experiment was laid in split-split plot design with three replications in which two cropping environments (poplar and sole onion) were considered under main plots, three planting times under sub plot and six varieties under sub-sub plot. The onion seedling was raised in bed size of 3m2 (spacing 15×10 cm) which was prepared for each variety planted at three planting times therefore counting 108 beds in total (54 each under poplar and sole onion). The four rows of beds were prepared in the alley of block plantation of poplar (clone L-47/88) spaced at 8×2.5m. Channels of 40 cm were left between the rows of beds for irrigation purposes. The details of cultural and managerial interventions followed in the field are shown in (Plate:1).

### *Morphometric observations*

For morphometric observations of onion bulbs, five plants were randomly assessed from each subplot for measuring plant height (cm; using 1m scale, height was measured from ground to the tip of longest leaf after 75 days of transplanting ), number of leaves per plant (count of green and functional leaves), neck thickness (cm; measured below the joint of leaf lamina, using a

digital vernier calliper), number of days to bulb initiation (using vernier calliper, neck diameter was measured on weekly intervals till it reached 2 mm or more, the initiation point of bulb formation) and number of days to maturity (considering of maturity indices of leaf drying and top fall).

### *Qualitative assessment*

The qualitative parameters assessed were total soluble solids (TSS) and dry matter content (DMC). The total soluble solids of fresh onion bulbs were observed in percentage value with the help of digital refractometer (0-30). The juice of fresh onion bulb was obtained by crushing in pestle-mortar. The average TSS was worked out from five selected bulbs. For DMC, twenty-five-gram fresh slices of bulb was weighed, placed in petri plates and dried in hot air oven at 65° C for 48 hours or till the consistent weight was obtained. The percent dry matter was calculated by using the following formula:

Dry Matter Content (%) = (Oven Dry Weight / Fresh Weight) × 100

## RESULTS AND DISCUSSIONS

### *Plant height (cm)*

Plant height is a crucial indicator of a plant's growth cycle that reflects its ability to compete for light and predictor of biomass production and yield. Among two cropping environments (poplar and open), plant height varied non-significantly (Table 1) which might be due to the fact that leafless period of poplar synchronized with the conditions to that of open, that resulted into lesser microclimatic variations between poplar and open conditions and therefore minimal vegetative growth difference. Averaged over varieties, height of onion plants decreased with delay in planting time from mid-December to mid-January. This might be due to the fact that early planted crop received favourable climatic conditions include temperature, humidity and days of length which might have helped in the enhancement of meristematic elongation of plant influencing the plants to put forth wider internodal length which in turn resulted in more plant height. Nesmith (1983) observed that any delay in transplanting beyond the optimum time can significantly impede the active growth phase of the transplants. Among the six onion varieties, PRO-7 was significantly taller (65.71 cm) than other varieties but at par with PRO-6 (64.35 cm) while Pb. Naroya showed minimum plant height (60.05 cm). Jilani *et al.* (2003); Sharma (2009) and Ram *et al.* (2011) observed significant genotypic variation among onion varieties for plant height. However, height of onion plants was observed to be lower under 5-year-old poplar than 4- year-old poplar which may be due to the changes in tree crop interaction with age effect.

### *Neck Thickness (cm)*

Neck thickness is an important factor in the selection of onion variety for extended storage life. In 2018-19, significantly more (1.29 cm) neck thickness was recorded under poplar as compared to open conditions whereas in the subsequent year, environments were found non-significant (Table 1). With the advancement of planting time, neck thickness reduced significantly with highest neck thickness (1.25 cm and 1.56 cm) recorded in mid-December followed by end- December (1.04 and 1.17 cm) and mid-January (1.00 and 0.91 cm) while among varieties, PYO-1 recorded significantly more neck thickness than other varieties but at par with Pb. Naroya. Neck thickness of bulbs varies with varieties as a specific character and sometimes it is also influenced by temperature and rainfall received during the cropping period. Identical research findings were reported by (Mahantesh *et al.*, 2005; Sharma, 2009 and Ram *et al.*, 2011). It was also observed that with the increase in age of poplar neck thickness also increased.(fig 1.)(fig 2.)




**Figure 1:** Pictorial representation of field experimental activities a) Preparation of bed rows under poplar b) Transplanting of onion seedlings c) Furrow irrigation channels d) Growth of onion under poplar canopy

**Table 1:** Vegetative growth attributes of onion varieties planted at three different times under poplar and open during 2018-19 (Y1) and 2019-20 (Y2)

| Treatments | | Plant height (cm) | | | Neck thickness (cm) | | | Leaves per plant (no.) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Y1 | Y2 | Mean | Y1 | Y2 | Mean | Y1 | Y2 | Mean |
| Environment | Poplar | 62.24 | 55.9 | 59.07 | 1.29 | 1.2 | 1.25 | 6.64 | 5.46 | 6.05 |
| | Open | 62.63 | 56.29 | 59.46 | 0.9 | 1.22 | 1.06 | 6.82 | 5.93 | 6.38 |
| | CD (0.05) | NS | NS | - | 0.11 | NS | - | 0.19 | 0.13 | - |
| Time of planting | Mid Dec | 64.69 | 65.18 | 64.94 | 1.25 | 1.56 | 1.4 | 7.41 | 6.08 | 6.74 |
| | End Dec | 61.92 | 54.33 | 58.12 | 1.04 | 1.17 | 1.1 | 6.46 | 5.82 | 6.14 |
| | Mid Jan | 60.7 | 48.78 | 54.74 | 1 | 0.91 | 0.96 | 6.32 | 5.2 | 5.76 |
| | CD (0.05) | 1.44 | 2.32 | - | 0.14 | 0.13 | - | 0.28 | 0.25 | - |
| Varieties | PWO-2 | 60.9 | 55.18 | 58.04 | 1.12 | 1.23 | 1.18 | 6.04 | 5.28 | 5.66 |
| | PRO-7 | 65.71 | 61.37 | 63.54 | 0.97 | 1.08 | 1.02 | 7.28 | 6.16 | 6.72 |
| | POH-1 | 62.39 | 55.87 | 59.13 | 1.04 | 1.12 | 1.08 | 6.57 | 5.51 | 6.04 |
| | Pb. Naroya | 60.05 | 51.98 | 56.02 | 1.15 | 1.29 | 1.22 | 6.91 | 5.86 | 6.38 |
| | PYO-1 | 61.23 | 54.52 | 57.88 | 1.2 | 1.37 | 1.28 | 6.51 | 5.46 | 5.98 |
| | PRO-6 | 64.35 | 57.66 | 61 | 1.1 | 1.19 | 1.14 | 7.06 | 5.93 | 6.5 |
| | CD (0.05) | 1.58 | 3.96 | - | 0.06 | 0.12 | - | 0.25 | 0.37 | - |




**Figure 2:** Leaf Fall pattern of Poplar from September to January

### *Number of leaves*

Leaves are the active site for photosynthesis, that determines the productivity level of a crop. During both the years, no. of leaves was significantly higher in sole crop (6.82 and 5.93) than under the poplar (6.64 and 5.46) (Table 1). The no. of leaves also affected by transplanting time and showed a declining trend with the delayed planting time. The maximum leaf number (7.41 and 5.93) was observed in mid-December planted crop followed by end-December (6.46 and 5.82) and mid-January (6.32 and 5.20) during both the experimental years, respectively. This could be attributed to favorable cool temperature experienced by younger seedlings which might have promoted maximum vegetative growth. Among varieties, PRO- 7 recorded maximum no. of leaves (7.28 and 6.16) than rest of varieties although at par with PRO-6 (7.06 and 5.93).

Overall, Variety PRO-7 revealed better growth with higher plant height, no. of leaves and desired neck thickness for different planting times under two environments, while Pb. Naroya recorded minimum plant height, no. of leaves and undesired neck thickness. Hamma (2013) reported that early transplanted crops complete their growth and developmental stages in more number of days than late planted crop. However, varietal variation in vegetative characters may be due to their genetic make-up. Thus, the increased no. of leaves, plant height, and neck thickness helped in better synthesis of carbohydrates and their utilization for the building of new cells.(fig 3.)

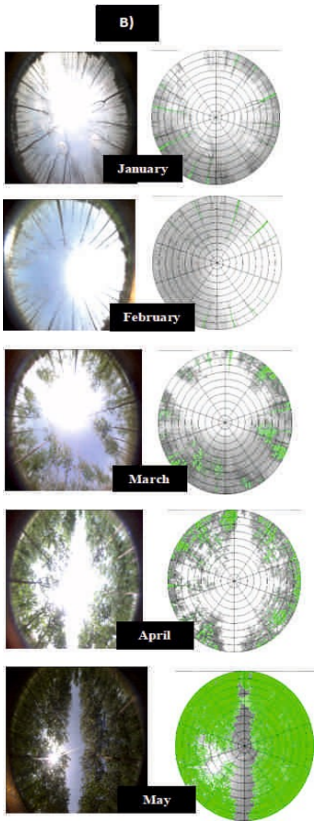



**Figure 3:** Leaf emergence and flushing of Poplar from January to May (Hemispherical images: Captured through Plant Canopy Analyser

### *Days to bulb initiation*

From the variation in environments the maximum no. of days to bulb initiation was observed under poplar (79.3 and 80.8) than open conditions (75.9 and 76.7) (Table 2). Among the planting times, mid-December planted crop took the maximum number of days to bulb initiation (81.5 and 83.1) followed by end- December (77.7 and 78.8) whereas mid-January planted crop took the minimum no. of days (73.6 and 74.3) to bulb initiation. Among the varieties, PRO-7 is an early maturing variety, so it took minimum no. of days to bulb initiation (67.3 and 68.7) which was significantly different from other varieties and followed by PRO-6. The maximum no. of days to bulb initiation was taken by variety PYO-1 (83.1 and 85.1). It was reported that bulb formation and subsequent growth were influenced by photoperiod and temperature (Lancaster 1996). Bulbing ratio gets increased with the increase of air temperature from 6 to 20°C and this also reduces the time to bulb maturity. Bulb formation is supplemented by long days and high temperature. There is a linear relationship between relative growth rate of bulbs and accumulated thermal time.

### *Days to maturity*

Among varieties (Table 2), maximum number of days to attain maturity was taken by PYO-1 (138 and 148.9) followed by POH-1 (145.2 and 146.7) while minimum number of days to maturity was noticed in PRO-7 ( 121 . 5 and 122 . 6 ) . The environments also significantly influenced duration to maturity; onion crop took more no. of days to mature under poplar (132.9 and 133.8) than under open (131.1 and 132.1) during both the years respectively. Early transplanted crop (mid-December) took more no. of days to attain maturity (142 and 142.9) than mid-January planted crop (122.8 and 123.6). Delay in transplanting time, shortens the crop cycle (Khokhar 2008 and Caruso *et al.,* 2014). This might be due to the fact that vegetative phase of late planted crop completes earlier due to the seasonal changes in temperature, light intensity and photoperiod of approaching summers. Following the declining trends in days to bulb initiation and maturity with the advancement of transplanting, the days of harvesting also followed the same trend (Bhardwaj *et al.,* 2021).

### *Crop Quality Parameters*

Onions are less perishable as compared to other vegetable crops; however, losses are unavoidable during storage. Bulb characteristics like dry matter, total soluble solids and pungency are determinant of storage life of onion.

### *Dry matter content (DMC) (%)*

The dry matter content showed non-significant difference among environments *i.e.* poplar and open for both the experimental years (Table 3). The results revealed significant influence of time of planting in the second year with the crop planted in mid- December produced highest dry matter content (13.12 %) as compared to end- December and mid- January. Among the six onion varieties, the maximum dry matter content was recorded in PWO- 2 (15.24%) which was significantly different from other varieties, while PYO-1 showed minimum percentage of dry matter content (10.71%) preceded by PRO-7 (11.6%). A similar trend was again observed in the successive year with highest dry matter content produced in PWO-2 (15.04%) followed by Pb Naroya (13.6%). The mean performance of the three planting times showed that maximum DMC was produced in mid-December planted crop and decreased towards mid-January planting time. This may also be due to increased production of photosynthates in early planted onion crop. These results are in accordance with the Bardisi *et al.* (2013) and Misra *et al.* (2014). The findings can also be supported by the explanation of Brewster (1982) that onion converts most of the photosynthates into harvestable products (harvest

**Table 2:** Number of days to bulb initiation, maturity and yield of six onion varieties planted at three different times under poplar and open during 2018-19 (Y1) and 2019-20 (Y2)

| Treatments | | Days to bulb initiation | | | Days to maturity | | |
|---|---|---|---|---|---|---|---|
| | | Y1 | Y2 | Mean | Y1 | Y2 | Mean |
| Environment | Poplar | 79.3 | 80.8 | 80 | 132.9 | 133.8 | 133.3 |
| | Open | 75.9 | 76.7 | 76.3 | 131.1 | 132.1 | 131.6 |
| | CD(0.05) | 0.94 | 3.4 | - | 0.21 | 0.56 | - |
| Time of planting | Mid Dec | 81.5 | 83.1 | 82.3 | 142 | 142.9 | 142.4 |
| | End Dec | 77.7 | 78.8 | 78.2 | 131.2 | 132.3 | 131.7 |
| | Mid Jan | 73.6 | 74.3 | 73.9 | 122.8 | 123.6 | 123.2 |
| | CD(0.05) | 1.8 | 1.88 | - | 0.63 | 0.65 | - |
| Varieties | PWO-2 | 79.2 | 81.6 | 80.4 | 133.7 | 134.6 | 134.1 |
| | PRO-7 | 67.3 | 68.7 | 68 | 121.5 | 122.6 | 122 |
| | POH-1 | 81.8 | 82.9 | 82.4 | 135.2 | 136 | 135.6 |
| | Pb Naroya | 78.8 | 80.6 | 79.7 | 132.6 | 133.7 | 133.1 |
| | PYO-1 | 83.1 | 85.1 | 84.1 | 138 | 138.9 | 138.5 |
| | PRO-6 | 75.3 | 73.5 | 74.4 | 131 | 131.8 | 131.4 |
| | CD(0.05) | 1.64 | 1.79 | - | 1.4 | 1.4 | - |

**Table 3: Quality parameters (DMC and TSS) of six onion varieties planted at three different times under poplar and open during 2018-19 (Y1) and 2019-20 (Y2)**

| Treatments | | DMC (%) | | | TSS (%) | | |
|---|---|---|---|---|---|---|---|
| | | Y1 | Y2 | Mean | Y1 | Y2 | Mean |
| Environment | Poplar | 12.54 | 11.71 | 12.12 | 12.15 | 10.83 | 11.49 |
| | Open | 13.1 | 12.52 | 12.81 | 12.52 | 10.61 | 11.57 |
| | CD(0.05) | NS | NS | - | NS | NS | - |
| Time of planting | Mid Dec | 13.34 | 13.12 | 13.23 | 12.79 | 10.72 | 11.75 |
| | End Dec | 12.89 | 11.99 | 12.44 | 12.3 | 10.56 | 11.43 |
| | Mid Jan | 12.23 | 11.23 | 11.73 | 11.93 | 10.89 | 11.41 |
| | CD(0.05) | NS | 0.44 | - | NS | NS | - |
| Varieties | PWO-2 | 15.24 | 15.04 | 15.14 | 13.85 | 12.37 | 13.11 |
| | PRO-7 | 11.6 | 10.54 | 11.07 | 12.86 | 11.58 | 12.22 |
| | POH-1 | 12.24 | 11.87 | 12.06 | 11.67 | 10.08 | 10.88 |
| | Pb Naroya | 13.11 | 12.73 | 12.92 | 12.47 | 10.94 | 11.71 |
| | PYO-1 | 10.71 | 8.88 | 9.8 | 11.14 | 8.91 | 10.02 |
| | PRO-6 | 14.02 | 13.6 | 13.81 | 12.04 | 10.46 | 11.25 |
| | CD(0.05) | 0.93 | 0.8 | - | 0.88 | 0.63 | - |

index 70-80%), but because of the shape and arrangement of the leaves; it is inefficient at intercepting incoming radiation. It is therefore important to encourage as much leaf growth as possible, early in the season, so that total light interception is maximized. The more leaves were produced by early transplanted crop which might have intercepted more radiation leading to accumulation of higher dry matter in bulbs.

### *Total soluble solids (%)*

Total soluble solids in onion bulbs were recorded significant for varieties (Table 3). In 2018-19, the highest TSS was found in PWO-2 (13.85 %) which was significantly higher than other five varieties; the lowest TSS was recorded in PYO-1 (11.14%). No significant effect of environments and transplanting times was observed for TSS in different varieties of onion for both the years. During 2019-20, a similar trend was noticed with highest TSS recorded in PWO- 2 (12.37%) while, lowest TSS was recorded in PYO-1 (8.91%). The significant variation in TSS among varieties may be due to the variation in moisture content and varietal properties. Gouda *et al.* (2016) explained that biochemical properties vary with genotype of varieties.

## CONCLUSION

It may be concluded that early transplanting (Mid- December) of onion varieties under poplar substantially influenced morphological and qualitative attributes. The morphological features (height, leaves, neck thickness, days to bulb initiation and maturity) of variety PRO-7 found to be better amongst all the varieties screened which is the resultant of effective interactions between environment, time of transplanting and varieties. However, with respect to qualitative attributes (DMC and TSS) variety PWO-2 outperformed other varieties in nutritional aspects. Therefore, the present study highlights that the consecutive yearly cultivation of onion under poplar adds value and scope to the raising and recommending of high value vegetable crops to the farming community. Because the growing of vegetables apart from cereal/pulses is another way of enhancing diversifications and ensuring economic security. The economic feasibility of onion + Poplar agroforestry system is evaluated by Bhardwaj *et al.* (2021) under sensitivity analysis and hence forth proved vi-

able agroforestry system. The present study also raises the future scope for other high value vegetable crops that can be successfully grown as intercrop with poplar. The approach of vegetable- based agroforestry is one of the means to increase the resilience of agrobiodiversity under challenging and adverse climatic conditions.

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