

Selecting walnuts from seedling tree populations in some villages of district Sirmour (HP)

THESIS

by

RITU SHARMA

*Submitted in partial fulfilment of the requirements for
the degree of*

MASTER OF SCIENCE

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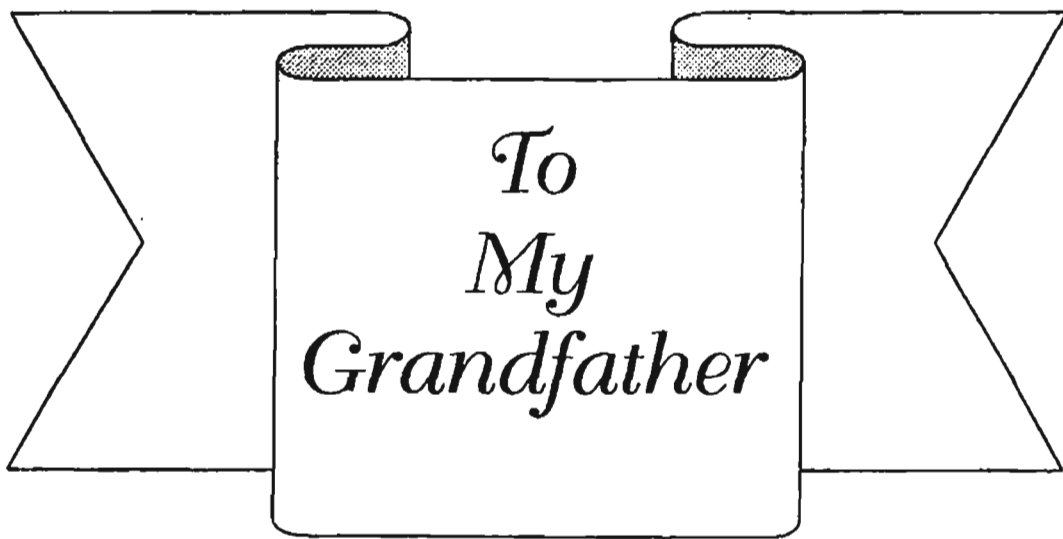
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*To
My
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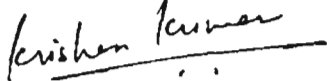
CERTIFICATE-I

This is to certify that the thesis entitled “**Selecting walnuts from seedling tree populations in some villages of district Sirmour (HP)**” submitted in partial fulfilment of the requirements for the award of degree of **MASTER OF SCIENCE in HORTICULTURE (Fruit Breeding & Genetic Resources)** to Dr Yashwant Singh Parmar University of Horticulture & Forestry, Solan (H.P.) is a record of bonafide research work carried out by **Ms Ritu Sharma (H-2000-17-M)** under my guidance and supervision and that no part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of research work have been fully acknowledged.

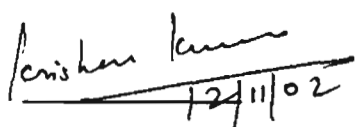
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This is to certify that the thesis entitled "Selecting walnuts from seedling tree populations in some villages of district Sirmour (HP)" submitted by Ms Ritu Sharma (H-2000-17-M) to Dr.Y.S.Parmar University of Horticulture and Forestry, Solan (H.P.), in partial fulfilment of the requirements for the award of degree of **MASTER OF SCIENCE in HORTICULTURE (Fruit Breeding & Genetic Resources)** has been approved by the Student's Advisory Committee after an oral examination of the same in collaboration with the External Examiner.


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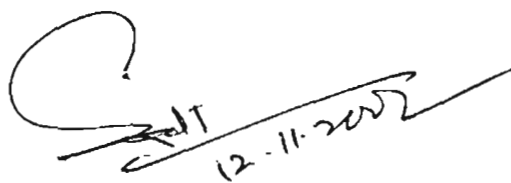
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To err is human.

Place: Nauni, Solan
Date: August 29, 2002


(Ritu Sharma)

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Chapter-1
INTRODUCTION

INTRODUCTION

Persian walnut (*Juglans regia* L.) belongs to the family Juglandaceae and is indigenous to the wide region extending from the Carpathian mountains across Turkey, Iraq, Iran, Afghanistan and Southern Russia to northern India (McGranahan and Leslie, 1990). The estimated world production is 1,281,422 metric tonnes covering an area around 584,066 hectares (FAO, 2001).

Walnut kernel is a rich source of proteins (15-20%), fats (60-75%) and also contain good amount of carbohydrates, phosphoric acid and vitamins. Walnut kernel is consumed fresh and widely used in confectionery, bakery and for extracting edible oil. The walnut tree yields valuable timber, which is most suitable for carving, making furniture and butts of guns. The bark has got medicinal value, whereas the husk of the nut is used for dying.

Walnut is found growing in Himalayan region between the elevation of 1200 to 2150 m above mean sea level, yielding a produce of 31,000 metric tonnes from an estimated area of 30,200 hectares (FAO, 2001). Most of the produce, however, comes from seedling trees of unknown origin found growing scattered in the states of Jammu & Kashmir, Uttranchal and Himachal Pradesh.

Given the importance of walnut in terms of the enormous export potential and with a scope of diversification with suitable high value crop in an otherwise apple dominating region, walnut becomes a viable alternative for commercial cultivation in the hilly states. However, unlike in developed countries like USA and France where extensive breeding programmes have yielded the evolution of several high yielding

walnut cultivars with superior nut and kernel quality, walnut improvement in India is in a primitive stage.

The scattered walnut plantations in the hilly regions comprise of seedling trees of unknown pedigree. Thus, each tree raised from seed is a distinct genotype owing to dichogamy and wind pollination. As such, natural stands of seedling trees exhibit tremendous genetic variation in growth, yield, nut and kernel quality characteristics. Walnut, therefore, provides a typical example of crop improvement through exploration and evaluation of individual trees in seedling plantations via exploitation of its vast genetic variation created through natural cross pollination and perpetuation through seed and thus harnessing the natural selection facilitated by extreme climatic diversities.

Since perennial fruit tree breeding is a cumbersome and time consuming process, selection of trees with desirable traits from existing bearing tree stands is a viable approach to develop superior cultivars.

In Himachal Pradesh, field surveys in the past have been undertaken in district Kullu, Shimla, Chamba, Mandi and Kinnaur to select superior genotypes, but not to a considerable extent in Sirmour district. Preliminary surveys in the area indicated the existence of several trees of seedling origin with high yield and good fruiting characteristics. In view of the above, field surveys were undertaken to screen persian walnut trees of seedling origin growing in some villages of district Sirmour of Himachal Pradesh with the following objectives:

1. To survey and screen the walnut seedling tree populations to select genotypes with superior economically important traits.
2. To characterise and evaluate seedling tree selections with superior growth, flowering, fruiting and yield characters.

Chapter-2

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Variability among the living organisms is a rule in nature. Traditionally and in some cases even today the walnut trees are propagated by seeds. In view of diversity of natural seedling tree stands of walnut, there lies a possibility to make selection within them. The selection has played a significant role in the improvement of all cultivated species and also in broadening the genetic base in many countries including India. The fundamental principle of selection is that it never creates variation but it exploits the existing variation. The various characters taken up for selection of desirable walnut seedlings include tree, foliage, floral and nut/kernel characters. The literature available on these aspects has been reviewed as under:

2.1 TREE CHARACTERS

Tree vigour, yield, growth habit and branching are important tree characteristics in any crop plant evaluation study.

2.1.1 Tree yield

Yield in any sense is a complex character. High yielding capacity is an important character which determine the economy of walnut production. The yield of nuts is governed by bearing habit, bearing surface, fruit set and nut size. Sharma and Chauhan (1980) recorded variation in yield ranging from 15 to 45 kg per tree among the trees having age between 20 to 25 years. Whereas in another study by Levina and Ulyukina(1981) the yield of 20 year-old trees reached 5-10 kg/tree. Pandey and Sinha (1984) selected some prominent seedlings of walnut from Jaunsar Bhabhar area of Garhwal hills and reported the yield (nuts/tree) to vary from 1000 in 'Chakrata No.8'

to 5500 in 'Chakrata No.1'. Paunovic (1990) evaluated 2500 seedling trees for yield and other characters. Out of which five trees were selected and 'T2' was recorded to be highest yielder (169 kg/tree). Among the 250 preselected genotypes of walnut in Iran, Atefi (1993) identified 'B21-1' as highest productive clone with 330 nuts per tree followed by 'K87-1' with 134 nuts/tree in four year-old trees. Other clones like 'B21', 'K20', 'K23', 'K78' were in a group that gave highest yield in the fourth year. In another study, Atefi (1997) obtained a yield of 35 kg/tree from cultivar K-21/3. Sharma and Sharma (1997a) studied bearing seedling walnut trees in Western Himalayas and recorded that yield varied from 0.5-105 kg/tree. Sharma and Sharma (1998a) observed that range of yield per tree was 3 to 40 kg, 8 to 75 kg and 16 to 105 kg in seedling trees with age of less than 20 years, 21-40 years and more than 40 years, respectively, in Jaunaji area of district Solan of Himachal Pradesh. Sharma (1999), while studying the variability in 229 seedling trees in Himachal Pradesh, recorded maximum yield of 130 kg in Tree No. 43 from Bharmour area of district Chamba while minimum yield of 1.5 kg in Tree No.7 from Garsa valley of district Kullu. In another study on walnut seedling trees from Shimla district of Himachal Pradesh, Attar (2001) observed that yield in the 27 selected trees varied from 40 kg/tree (RS-23, CS-11) to 105 kg/tree (CS-36).

2.1.2 Trunk girth and trunk cross-sectional area

Trunk girth and trunk cross-sectional area are two important growth characteristics which reflects the tree vigour and yield potential in walnut. In Jammu & Kashmir, there are several centuries old seedling trees which have attained a height of 45 meters and girth upto 11 meters (Dewan *et al.*, 1992). During their studies on variability in Solan district of Himachal Pradesh, Sharma and Sharma (1997a) recorded the trunk girth ranging from 50-497 cm among 125 bearing seedling trees. Sharma and Sharma (2000 a) in their studies on variability in 229 seedling trees in Himachal Pradesh also observed significant variations in trunk girth and trunk cross-sectional area.

2.1.3 Growth habit and branching

As regards the habit and vigour of the tree, Forde (1975) stated that an ideal tree will grow vigorously to moderate in size and then slow down to produce nuts in abundance.

In a study carried out by Radicati *et al.* (1990), out of 17 cultivars, 'Sorrento 3' was most vigorous whereas 'Chase D9' was least vigorous. In another study by Aleta and Ninot (1993) trees usually showed a semi-erect growth habit and vigorous growth except 'MB-T-363' having low vigour. Spreading growth habit was more common in Atlantic region and the vigour was higher in seedling trees from the Mediterranean area (Aleta and Ninot, 1997). Among 128 walnut seedling trees growing in Jaunaji area, Solan district, India, 32 trees were spreading, 38 semi-spreading, 33 semierect and 32 erect (Sharma and Sharma, 1997a). The branching density of 229 selected types from seedling population in Himachal Pradesh varied from 3 to 12 branches per metre unit shoot length (Sharma and Sharma, 2000b). A maximum of 12 branches per unit shoot length were observed in 'Tree No.31' and 'Tree No.55' in Chamba.

Attar (2001) observed 53 trees to be spreading, 16 semi-erect, 4 erect in Sarahan area; 62 spreading, 20 semi-erect and 2 erect in Rohru area; and 33 spreading, 15 semi-erect and 7 erect in Chopal area of district Shimla.

2.2 FOLIAGE CHARACTERS

Late leafing time is a desired character in walnut to avoid damage due to spring frosts. However, Bugarcic *et al.* (1985) reported that the most productive genotypes come into leafing either very early or late and early leafing forms also produced the largest fruits. The late leafing time (Sharma and Sharma, 2000a) in Mandi, Kullu, Sirmour and Chamba was observed on 5th April, 8th April, 15th April and 25th April, respectively. Solar (1990) observed earliest signs of leaf fall in cv. G-1247 on 19th October whereas the latest on the cv. MB-24 on 2nd November. According to Sharma and Sharma (2000a) leaf fall in walnut trees of seedling origin

extended from 29th September to 25th November in Kullu, 28th August to 12th November in Mandi, 15th August to 16th September in Sirmour and 15th September to 20th November in Chamba.

Singh (1993) observed 49 per cent trees with elliptic leaflets, 27.47 per cent with broad elliptic and 13.72 per cent with narrow elliptic to elliptic leaflets in a bearing seedling population of walnut in Kullu valley. Lee *et al.* (1994) found considerable variation in foliage characters such as compound leaf length, width, number of lateral veins in top leaflet, top leaflet base angle and area. Variation in number of lateral leaflets ranging from 4 to 12 has been reported from walnut trees of seedling origin in Himachal Pradesh (Sharma and Sharma, 1998a, 2000a).

2.3 FLORAL AND FRUITING CHARACTERS

Walnut is a monoecious plant and heterodichogamous (Meza, 1975) dichogamic in nature. Time of male and female flowering, number and size of male catkin and bearing habit of trees are some of the most important criteria in characterization, evaluation and selection.

Mitrovic (1988) reported that selection 'Ovcar' had the earliest pollen dispersal (28th April) and 'Novosadskikasni' the latest (16th May) in Cacak area of Yugoslavia and the pistillate flowers showed earliest stigma receptivity in 'Dorka' (2nd May) and latest in 'Novosadskikasni' (22nd May). Out of 95 walnut types, Sen (1993) reported protandry in 69 types, protogyny in 13 types and homogamy in the remaining 13 types.

In a selection programme for high yield and good quality, Rouskas *et al.* (1997) observed 'FOPAN1' and 'FOKA1' to exhibit homogamy. Aleta and Ninot (1997) observed that the Atlantic Coast walnut clones had a high proportion of trees showing intermediate flowering. Ribeiro da Silva *et al.* (1997) recorded earliest male flowering in cultivars 'Payne' and 'Arco' on 27th March and latest in 'Franquette' on 15th May. The variation in female flowering time was less as compared to male flowering time (Sharma and Sharma, 1998a) and all 125 trees were protandrous in

nature. In another study Sharma and Sharma (2000a) recorded variation in time of catkin bud burst, male and female flowering in 229 walnut trees of seedling origin. All these trees were found to be protandrous in nature except 'Tree No.11' in Nohradhar (Sirmour) which was protogynous. Rouskas and Zakyntinos (2001) observed two homogamous selections, 21 protogynous and 34 protandrous. Sutyemez (2001) selected 24 homogamous types from a population of 171 trees in which the male and female flowering time overlapped atleast for six days.

As regards hull persistence on tree after nut fall, cultivars 'Geisenheim 139' and 'Tehama' had fully persistent hulls, cultivar 'Pedro' had partially persistent hulls whereas hull persistence was absent in 'Franquette', 'Hartley' and 'Parisienne' (UPOV, 1988). In a study carried out by Attar (2001) on 27 selected walnut seedling trees, 21 were found to have slight hull persistence after nut fall and six trees were having moderate hull persistence after nut fall. Variation for hull dehiscence was also observed in the same study where in 24 selected trees showed dehiscent nuts only three selections produced nuts having slight hull dehiscence.

2.4 NUT AND KERNEL CHARACTERS

For the nut and kernel, a high quality is essential in persian walnuts. The desired nut size is large for the in-shell market (12 to 14 g or more) and medium to small (9 to 11 g) for the kernel market (Germain, 1992). Nut quality depends on the colour, shell strength and thickness, smoothness, shell seal, kernel percentage, kernel colour and ease of kernel removal.

2.4.1 Nut characters

Ideal nut should have relatively thin shell, easy to break, smooth, well lignified and with well sealed halves. Nine promising walnut strains in Chakrata hills of Uttar Pradesh were studied by Lal and Singh (1978) and in their study, average nut/fruit weight varied from 5.0 g (Chakrata Lehman Kagzi) to 17.6 g (Hanaul Kagzi) whereas shell thickness varied from 0.20 cm (Chakrata Lehman Kagzi) to 0.28 cm (Kuna Kagzi). In a study carried out by Chauhan and Sharma (1979) in Kinnaur district of

Himachal Pradesh, the average nut weight varied from 6.24 g (Seedling 18) to 15.35 g (Seedling 11), nut length from 2.63 cm (Seedling 24) to 4.78 cm (Seedling 29), nut diameter from 2.20 cm (Seedling 34) to 4.00 cm (Seedling 37) and shell thickness from 0.08 cm (Seedling 16) to 0.43 cm (Seedling 28). In a different study (Sharma and Chauhan, 1980), the highest average nut weight (14.76 g) was obtained in Seedling 5 followed by Seedling 4 (14.38 g). However, the Seedling 1 produced lightest (6.73 g) and longest nuts (4.15 cm), whereas Seedling 2 produced the shortest nuts (3.22 cm). The highest nut diameter was obtained in Seedling 6 (3.71 cm) whereas the least was obtained in Seedling 9 and 11 (2.85 cm). The shell thickness of nuts ranged from 0.10 cm in Seedling 11 to 0.35 cm in Seedling 14. Considerable variability in respect of harvesting period was observed in various seedling selections and Seedling 1 was the earliest as its fruits were harvested in the 2nd week of August whereas Seedling 14 ripened last of all (last week of September). Sen (1983) evaluated fruit samples from 550 *Juglans regia* trees collected from Anatolia and eastern Black sea regions of Turkey in 1977-1979. In the 26 types selected from the above study, average nut weight was 11.29 g and average shell thickness was 1.23 mm.

Out of preselected 50 seedling trees from Jaunsar Bhabhar area of Garhwal Hills, Pandey and Sinha (1984) selected 15 seedling trees on the basis of fruit quality, size, yield etc. Chakrata No.1 bore maximum of 5000-5500 nuts/tree. Nut weight varied from 26 g in 'Chakrata No.1' to 8 g in 'Chakrata No.9', fruit length from 5.53 cm in 'Chakrata No.4' to 4.27 cm in 'Chakrata No.13' and fruit width varied from 4.68 cm in 'Chakrata No.2' to 3.10 cm in 'Chakrata No.14'.

According to Strila *et al.* (1988), out of 23 new forms selected in the Ukraine during plant collecting expeditions and grown in the Kiev area, 78.3 per cent trees had large or moderately large fruits weighing 10 to 14 g each. Shells were 0.8 to 1.2 mm thick in 65.2 per cent of forms (average value 0.94 mm) and the nuts cracked readily. In a study (1980-83) of walnut forms from a natural population in Yugoslavia, Miletic (1986) observed fruit weight varying from 7.6 to 16 g and shell weight from 3.7 to 8.7 g. Fruits were predominantly or slightly elongated, the shell being light and fairly easy to crack. In a study carried out by Solar (1990) in North-eastern Slovenia, the nut

produced on the cv. G-120 was the heaviest (13.40 g) and the nut of cv. Sejnovo, the lightest (9.00 g). Sen and Tekintas (1992) reported 12 walnut types having fruit weight above 15 g.

Out of nine cultivars previously selected from 116 biotypes, 'Kaplan 86' had highest fruit weight (23 g) while cv. Sebin had lowest fruit weight (10 g) (Ferhatoglu, 1993).

In a study carried out by Akca and Sen (1994), 41 superior types were selected as promising from a population of 365 trees of seedling origin. The mean nut weight of selected types varied from 10.36 in 'Type No.40' to 19.6 g in 'Type No.2', nut length varied from 38.15 mm in 'Type No.41' to 50.84 mm in 'Type No.1', and shell thickness varied from 0.59 mm in 'Type No.40' to 1.47 mm in 'Type No. 51'.

Rouskas *et al.* (1997) observed average nut weight ranging between 18 g (Fok A1) and 25 g (FM 3) in a study carried out in Greece. Kuden *et al.* (1997) observed that AS-2 (19.3 g) and Kam-12 (18.1 g) gave the best results for fruit weight. Variation was also recorded for nut characters in walnut seedling trees from Himachal Pradesh (Sharma, 1999; Sharma and Sharma, 1997a, 2001; Gautam, 2000; Attar, 2001), Iran (Atefi, 2001) and Turkey (Kazankaya *et al.*, 2001).

2.4.2 Kernel Characters

Kernel of walnut, the edible portion, constitutes about half of the total fruit weight. Whereas the kernel should have a light colour, should be plump and easily extractable. It should represent between 48 and 55 per cent of the nut weight (Germain, 1992). According to Yadrov and Popov (1998) the kernel percentage of selected types should not be less than 45 per cent.

Earlier, Serr and Forde (1956) suggested that an ideal selection should have above 50 per cent shelling percentage.

Variety 'Mirkovski' developed by Trifonov (1972) had kernel yield of 48.10 per cent. Over a 16 year period, 40 seedlings grown from fruits collected from all over

southern Poland showed substantial differences with regard to tree and fruit characteristics (Kropp *et al.*, 1972). Reported kernel weights in seedling trees and selections from different studies ranged from as high as 10.0 to 11.0 g to as low as 2.0 g (Sykes, 1975; Cheng, 1978).

According to Chauhan and Sharma (1979) highest kernel percentage (64.33%) was recorded in Seedling 34 and lowest percentage (28.84%) in Seedling 1. In another study by Sharma and Chauhan (1980) as regards kernel percentage, Seedling 11 produced the nuts with highest percentage of kernels (52.65%) whereas the lowest kernel percentage (24.08) was obtained in Seedling 7. Sen (1983) reported average kernel weight of 6.2 g and 87.89 per cent of light yellow kernels in his selection programme. Rathore (1984) recorded the average kernel weight between 1.2 g to 4.6 g in an evaluation study of 22 walnut accessions while Esayan and Bassegyan (1983) selected 100 walnut trees for nut analysis and found that maximum trees had high kernel yield (60% or more). Strila *et al.* (1988) selected 23 new forms in the Ukraine with 57.6 per cent average yield of kernels. Kernel oil and protein content varied from 53.34 to 74.83 per cent and 2.56 to 21.81 per cent, respectively. The mean values for kernel weight varied from 5.0 g in cv. 'Chico' to 9.9 g in cv. 'Sunland' (McGranahan and Leslie, 1990) while the percentage of the kernel content was highest (55.22%) in cv. Sejnovo and the lowest (42.84%) in cv. G-120 (Solar, 1990). Among the observed phenotypes in another study, cv. 'Malizia' was adjudged the best with a yield of 46.49 per cent light coloured kernels (Limongelli, 1993).

In Parvati valley in Kullu district, Singh (1993) observed considerable variation in seedling trees with respect to kernel weight (3.06-8.06 g), kernel width (1.6-2.85 cm), kernel length (1.88-3.43 cm), kernel breadth (1.64-3.03 cm) and kernel percentage (25.20-64.14%). Akca and Sen (1994) recorded variation in kernel weight from 5.77 g (Type No.16) to 9.41 g (Type No.1), kernel to nut ratio from 46.1 per cent (Type No.56) to 64.2 per cent (Type No.40) and light yellow kernel colour varied from 50-100 per cent in the selected types. Godeanu and Botu (1997) recorded highest kernel percentage of 55.3 per cent in hybrid H2/5. Rouskas *et al.* (1997) recorded highest kernel percentage of 51 per cent in Fok A1 and lowest of 42 per cent in FK3.

In a study carried out by Kuden *et al.* (1997), the highest kernel percentage was obtained from Klan-8 (57.39%), Kam-10 (56.01%), Kam-12 (56.35%) and Kam-9 (56.30%) and lowest from D1 (41.44%) while kernel weight varied from 4.3 g (Klan-8) to 10.2 g (Kam-8). Gupta (1999) observed variation in kernel thickness, kernel width, kernel height, kernel weight and kernel percentage extending from 3.01 cm (Inder Akhrot) to 1.78 cm (Plant No.25), 3.54 cm (Inder Akhrot) to 1.64 (KxGiant), 3.44 cm (Inder Akhrot) to 1.99 cm (Hartley) and 7.56 g (Inder Akhrot) to 1.47 g (KxGiant), respectively.

Several recent reports from different parts of the world also indicate variation in kernel colour, weight, percentage etc. in walnut germplasm (Gautam, 2000; Atefi, 2001; Yarilgac *et al.*, 2001; Kazankaya *et al.*, 2001; Sharma and Sharma, 2001).

2.5 CHEMICAL ANALYSIS

For the selection of genotypes with superior kernel quality in walnut, protein and oil contents are considered to be the most stable characters. As reported by Watt and Merrill (1963), kernel consists of 64.0 per cent of fat and 14.8 per cent of protein in its composition. Variety 'Mitrovski' developed by Trifonov (1972) contains 68.03 per cent oil and had good flavour. Among 40 seedlings grown from fruits collected from all over southern Poland, the 5 most valuable genotypes had 57 to 62.4 per cent oil and 11.2 to 12.20 per cent crude protein content (Kropp *et al.*, 1972).

Sharma (1979) reported that protein content ranged from 6.47 to 18.77 per cent in selections from one locality and 6.25 to 22.5 per cent in selections from another locality. From a 20 year-old population of 530 walnut trees, Levina and Ulyukina (1981) recorded average of 69 per cent oil, 18 per cent carbohydrates and 4.5 per cent nitrogen in the kernels. In a study carried out by Esayan and Bassegyan (1983), out of 100 selected trees of walnut maximum trees had high fat (55.70%) and protein contents (15-20%).

Sen (1983) examined 550 individual walnut trees and of these, 26 were selected with average fat content of 70.8 per cent and protein content of 20.52 per

cent. In Yugoslavia, Bugarcic *et al.* (1985) observed that the oil in the kernel ranged between 61.0 and 72.5 per cent and protein between 10 and 19.94 per cent. Whereas Strila *et al.* (1988) reported that the oil varied from 34.83 to 53.34 per cent and protein from 2.56 to 21.81 per cent in their studies. Dong (1990) described seven elite forms which had oil content from 71.5 per cent to 74.0 per cent. While, Singh (1993) recorded variation in fat and protein contents of persian walnut from 41.78 to 67.34 per cent and 8.23 to 18.99 per cent, respectively. In his comparative studies on the biological and pomological characteristics of walnut cultivars and selections, Mitrovic (1992) observed highest oil content (72.5% in G139) and mean oil content as 68.8 per cent. In nine cultivars obtained through selection by Ferhatoglu (1993), the oil content ranged between 79 per cent (Yalova 3) and 67 per cent (Sebin) and protein content varied from 21 per cent (Yalova 3) to 16 per cent (Yalova 4). Mitrovic *et al.* (1997) found that the protein and oil content varied from 16.11 (Vujan) to 13.00 (4-251) and 74.46 per cent (4-251) to 66.12 per cent (Vujan), respectively. Sharma (1996) recorded highest fat percentage (67.27%) in 'Tree No.39' and lowest (37.15%) in 'Tree No.90' while the highest protein percentage (25.08%) was recorded in 'Tree No.90' and lowest protein percentage (5.30%) was present in 'Tree No.39'. Sharma and Sharma (1997b) recorded the variation in protein and fat percentage of seedling walnut from 6.36 (Cv.No.17) to 25.05 per cent (Cv. No.57) and 37.15 (Cv. No.57) to 63.27 per cent (Cv. No.17), respectively. Similarly, reports of variation in kernel oil and protein content in walnut selections have come up from Yugoslavia (Miletic *et al.*, 1999) and Turkey (Akca and Sen, 1994; Yartilgac *et al.*, 2001).

2.6 CORRELATION STUDIES

In a phenotypic correlation study among 18 different traits, Hansche *et al.* (1972) observed high positive correlations between leafing, flowering and harvest dates. Nut weight was found to highly correlated with nut length (0.62), suture (0.72), cheek (0.78) and kernel weight (0.82). Sharma (1996) observed positive association of yield with girth, kernel width and kernel thickness of nut weight with nut width, nut height, nut thickness, pad width, pad thickness, kernel width, kernel height and kernel thickness. In another study, Sharma (1999) observed that yield efficiency showed

positive and significant correlation with density of branching (0.267), nut weight (0.287), nut width (0.277), nut height (0.231), nut thickness (0.322), kernel weight (0.324), kernel width (0.345), kernel height (0.191), kernel thickness (0.313) and kernel percentage (0.148) and negative and significant correlation with protein percentage (-0.192).

Sharma and Sharma (2001) on the basis of correlation studies reported that nuts having lower value of shell thickness should be selected to get increased kernel weight and kernel percentage. They also concluded that heavy nut weight, longer nut height, larger value of nut width, more kernel weight, width, height, thickness, kernel percentage and fat percentage will lead to lesser protein percentage.

2.7 PATH ANALYSIS

In the direct and indirect effects of various characters on yield worked out at phenotypic level by Sharma (1999), trunk girth (0.7831), yield efficiency (0.4488), nut width (0.1153), density of branching (0.1148), nut weight (0.0783), kernel percentage (0.0606), fat percentage (0.0434) and protein percentage (0.0121) showed direct positive effects whereas trunk cross-sectional area (-0.0444), catkin length (-0.0296), duration of female flowering (-0.0583), nut height (-0.0536), shell thickness (-0.0749), nut thickness (-0.0259), kernel weight (-0.0017), kernel width (-0.0068), kernel height (-0.0089) and kernel thickness (-0.0698) showed direct negative effects on yield. Trunk cross-sectional area showed positive indirect effect on yield via trunk girth (0.7624).

In another study carried out by Sharma and Sharma (2001) the path analysis results at phenotypic level revealed that kernel weight had highest positive direct effect on nut weight followed by nut thickness, pad width, nut height, kernel thickness and pad thickness. The direct positive effect of these characters are high, so it can be concluded that by selecting higher values for these characters, nut weight can be increased considerably.

Chapter-3

MATERIAL AND METHODS

MATERIAL AND METHODS

A field survey was undertaken to select superior walnut trees of seedling origin from villages viz. Chauras, Chikhria (Ser Tundla), Khal, Gandoori and Deedag in district Sirmour of Himachal Pradesh, located around 1600 m above mean sea level between 30.33°N latitude and 77.21°E longitude (Fig. 1).

Personal interactions were held with the owners of a total of 342 walnut trees to assess their overall growth and performance. On the basis of the information given by the owners, the trees which were irregular or not in bearing in 2001 and those bearing extremely hard shelled nuts were not included in further evaluation studies.

Observations on various tree, foliage, flowering, fruiting, nut and kernel characters were recorded as per the IPGRI descriptors (IPGRI, 1994). In addition, biochemical analysis was carried out for evaluation of kernel quality following standard procedures. The details are as under:

3.1 TREE CHARACTERS

3.1.1 Trunk cross-sectional area (TCSA)

The trunk cross-sectional area was calculated as per the method given by Westwood (1993).

$$\text{TCSA} = \pi r^2$$

where,

r = radius of the trunk

3.1.2 Tree yield

Nuts from individual trees were hulled and dried in sun, to record the yield expressed in kilograms/tree.

3.1.3 Yield efficiency

The yield efficiency was calculated by adopting a method suggested by Westwood (1993) as under:

$$\text{Yield efficiency (kg/cm}^2\text{)} = \frac{\text{Yield (kg)/tree}}{\text{Trunk cross-sectional area}}$$

3.1.4 Growth habit (Fig.2)

Uprightness of vigorous current shoots was recorded and seedling trees were grouped into following categories:

- i) Spreading: Side branches were spreading outwards and not competing with the central leader
- ii) Semi-erect: Branches grow upward and do not tend to compete with the central leader
- iii) Erect: Branches grow conspicuously upward and tend to compete with central leader

3.1.5 Branching density

The observations were recorded on the number of branches per metre shoot length on four scaffolds. On the basis of average number of branches, various seedling trees were divided into following classes:

- i) Sparse - <4
- ii) Medium - 4-6
- iii) Dense - >6

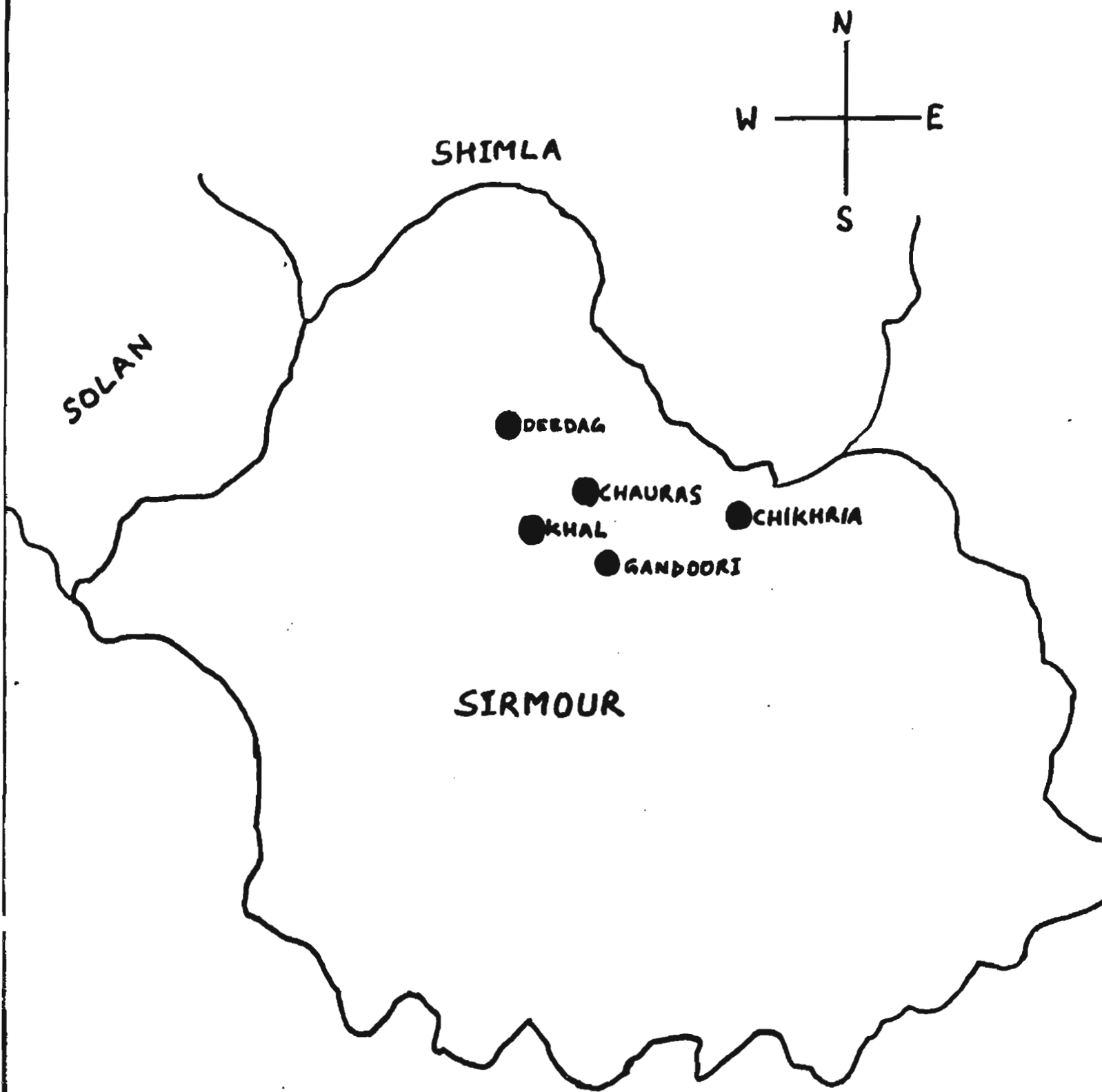
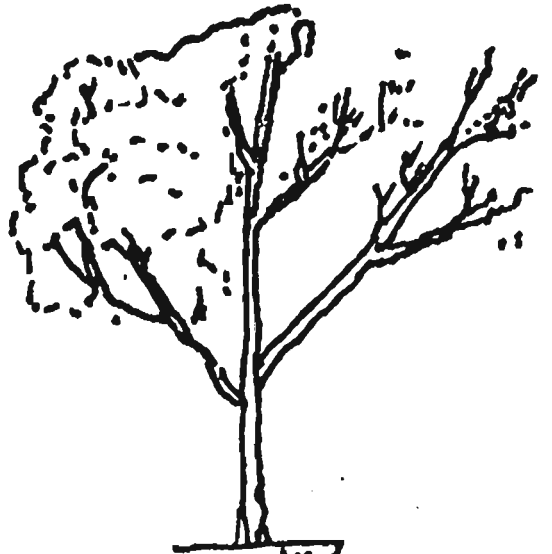


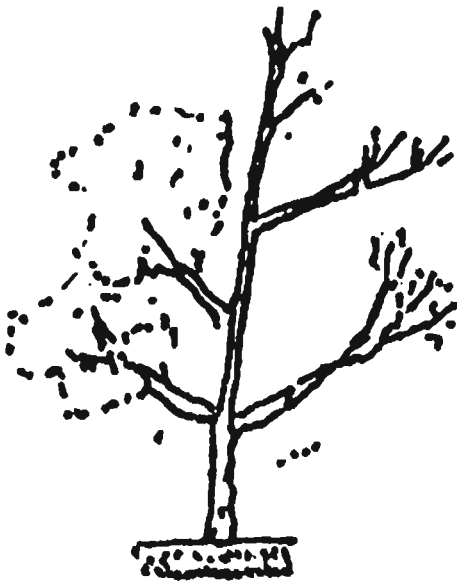
Fig. 1: Map showing different villages surveyed for selection of superior walnut trees in district Sirmour of Himachal Pradesh



Erect



Semi-erect



Spreading

Fig. 2. Growth habit

3.1.6 Shoot pubescence

Visual observation was recorded with respect to shoot pubescence on one year old shoots and following categories were made:

- i) Glabrous
- ii) Slightly pubescent
- iii) Pubescent

3.1.7 Shoot colour

Observations regarding one year old shoot colour was recorded visually and the following categories were made:

- i) Pale brown
- ii) Green brown
- iii) Blackish

3.1.8 Time and days to harvesting of nuts

The time of nut harvesting was recorded on the day of first signs of hull splitting. The days to nut harvesting was calculated from the date of peak female bloom to the date of harvesting the nuts.

3.1.9 Number of nuts per tree

The number of nuts harvested from each tree selection were counted.

3.2 FOLIAR CHARACTERS

For these characters, average of 10 fully expanded representative leaves from each selection were recorded.

3.2.1 Leaf length

Length of leaves was measured from the base of petiole to the tip of terminal leaflet and expressed in centimeters (cm).

3.2.2 Leaf width

Width of leaves was measured at the widest part and expressed in centimeters (cm).

3.2.3 Number of leaflets

The observation pertaining to number of leaflets was recorded on fully expanded leaves by counting its leaflets.

3.2.4 Leaflet width

The width of leaflets was measured at the widest part and measured in centimeters (cm).

3.2.5 Leaf colour

On the basis of visual observations with respect to leaf colour, the seedling tree selections were classified into following categories:

- i) Light green
- ii) Green
- iii) Dark green

3.2.6 Rachis colour

Rachis colour was observed visually and seedling trees were grouped into following classes:

- i) Green
- ii) Yellow
- iii) Red

3.2.7 Leaf and rachis pubescence

On the basis of visual observations on intensity of pubescence in leaf and rachis, seedling trees were classified into following groups:

- i) Glabrous
- ii) Slightly pubescent
- iii) Pubescent

3.2.8 Leaf and/or rachis persistence

Observations were recorded to know whether rachis abscises from point of attachment after all the leaflets fall or not and the following categories were made accordingly:

- i) A few remain attached to stem
- ii) Intermediate
- iii) Many remain attached to stem

3.2.9 Time and duration of leaf bud burst

The time of leafing out was recorded when over 50 per cent of terminal buds had enlarged and the bud scales had split exposing the green of the leaves inside. Duration of leafing time was calculated from 1st March (standard for all the seedling trees) till the end of leaf bud burst.

3.2.10 Time and duration of leaf fall

Date of the completion of 75 per cent leaf fall was recorded. For duration of leaf fall, time period between leafing time and leaf fall is calculated.

3.3 FLORAL AND FRUITING CHARACTERS

3.3.1 Degree of dichogamy

Degree of dichogamy was calculated (modified Solar *et al.*, 1997) as under:

$$\text{Dichogamy (\%)} = 1 - \frac{\text{Duration of male bloom (pollen shedding period) overlapped by female bloom (stigma receptivity period) duration}}{\text{Duration of female bloom (stigma receptivity period)}} \times 100$$

3.3.2 Nature of dichogamy

Observations were recorded on time of maturation of male catkins (indicated by pollen shedding) and female flowers (indicated by bifid stage of stigma receptivity) to determine the nature of dichogamy. Accordingly, the various selected trees were categorised as:

- i) Protogynous - when stigma receptivity precedes pollen shedding
- ii) Homogamous - when pollen shedding coincides with stigma receptivity
- iii) Protandrous - when pollen shedding precedes stigma receptivity

3.3.3 Bearing habit

The observations regarding the bearing habit was recorded at the time of female flowering and categorized as below:

- i) Terminal: Bears on the terminal portion of the newly growing shoots
- ii) Lateral: Bears on the terminal as well as lateral shoots

3.3.4 Female flower abundance

The intensity of female flowers, observed visually on each selected tree, was recorded as:

- i) Light
- ii) Intermediate
- iii) Heavy

3.3.5 Stigma colour

Visual observation on stigma colour was recorded and seedling trees were classified into following classes:

- i) Green
- ii) Yellow
- iii) Red

3.3.6 Hull persistence after nut fall

Observation was recorded to know whether hull persist after nut fall or not and on that basis seedling trees were grouped into following categories:

- i) Slight
- ii) Moderate
- iii) Significant

3.3.7 Hull dehiscence

Data with respect to degree of hull dehiscence in the matured fruits were recorded and various selections were classified into following categories:

- i) Non-dehiscent
- ii) Slightly dehiscent
- iii) Dehiscent

3.4 NUT AND KERNEL CHARACTERS

Twenty five randomly selected nuts from each tree selection were taken as representative sample to record observations on various nut and kernel characters.

3.4.1 Nut shape

The nut shape was determined following IPGRI (1994) descriptors in longitudinal section through suture and in longitudinal section perpendicular to suture.

- i) Shape of the nuts in longitudinal section through suture (Fig.3) was recorded as:
Circular, triangular, ovate, trapezoid, broad elliptic, elliptic and obovate.
- ii) Shape of the nuts in longitudinal section perpendicular to suture (Fig.4) was recorded as:
Circular, ovate, trapezoid, elliptic, cordate and obovate.

3.4.2 Nut diameter

The nut diameter (mm) was determined on the basis of diameter through suture and in perpendicular to suture using Vernier's Calliper in each case.

3.4.3 Nut length

Data on nut length (mm) of 25 randomly selected nuts from each seedling tree were recorded with the help of Vernier's Calliper and average was worked out.

3.4.4 Shell texture

Nuts of individual seedling trees were visually observed for smoothness of shell texture, and following classes were made:

- i) Very smooth
- ii) Smooth
- iii) Medium
- iv) Rough
- v) Very rough

3.4.5 Shell colour

Nuts of individual seedling tree were visually observed for shell colour, and the following categories were made:

- i) Very light brown
- ii) Light brown
- iii) Medium brown
- iv) Dark brown
- v) Very dark brown

3.4.6 Shell seal

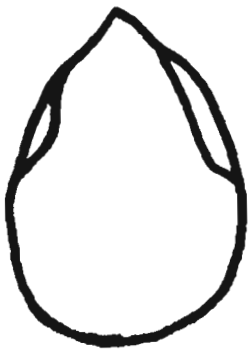
Visual observations of nuts of individual seedling tree were made for shell sealing and the following classes were made:



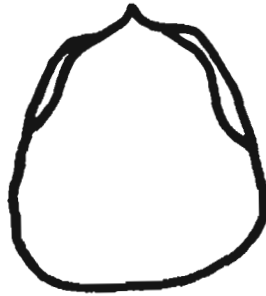
CIRCULAR



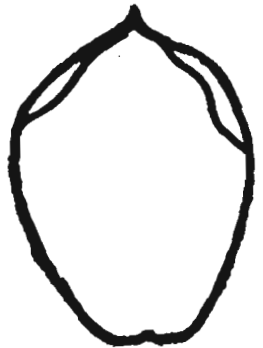
TRIANGULAR



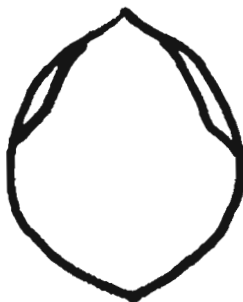
OVATE



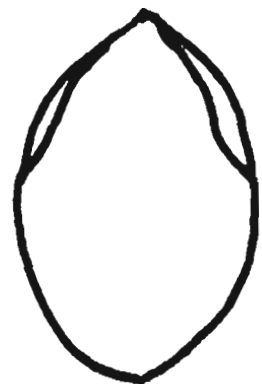
TRAPEZOID



OBOVATE

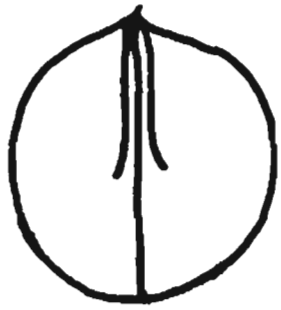


BROAD ELLIPTIC

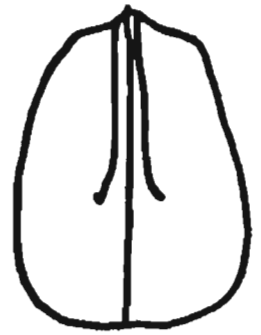


ELLIPTIC

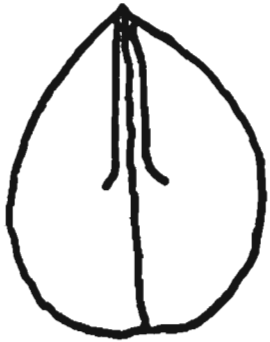
FIG.3. NUT SHAPE THROUGH SUTURE



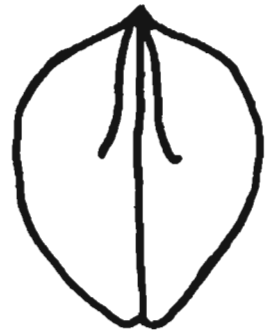
CIRCULAR



TRAPEZOID



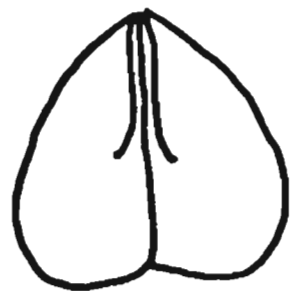
OVATE



OBOVATE



ELLIPTIC



CORDATE

FIG. 4. NUT SHAPE PERPENDICULAR TO SUTURE

- i) Open or very weak
- ii) Weak
- iii) Intermediate
- iv) Strong
- v) Very strong

3.4.7 Shell strength

The shell strength was determined manually by hitting the nuts with each other and was recorded as:

- i) Weak - when shell cracked without force
- ii) Intermediate - when shell cracked with force
- iii) Strong - when shell cracked with extra force

3.4.8 Shell integrity

Shell integrity was recorded in terms of completeness of shell to categorise various selections as under:

- i) Incomplete shell (>50% missing)
- ii) Intermediate (50% missing)
- iii) Complete shell, no holes

3.4.9 Shell thickness

Shell thickness was measured at near centre of half shell with the help of digital Vernier's Calliper. Shell thickness was expressed in millimeters (mm) as average of 25 randomly selected nuts.

3.4.10 In-shell nut weight

Twenty five randomly selected nuts were weighed on digital balance and average was worked out. In-shell nut weight was expressed in grams (g).

3.4.11 Kernel colour

The intensity of brown colour of kernels was visually observed in each tree to divide into following classes:

- i) Very light
- ii) Medium
- iii) Dark
- iv) Very dark

3.4.12 Kernel percentage

The kernel percentage was worked out as average of 25 randomly selected nuts from each tree using the formula:

$$\text{Kernel (\%)} = \frac{\text{Kernel weight}}{\text{Nut weight}} \times 100$$

3.4.13 Kernel weight

The weight of the kernel was recorded on the basis of kernel extracted from 25 nuts and average was worked out and expressed in grams.

3.4.14 Kernel veins

The percentage of kernel samples having conspicuous veins was calculated on the basis of visual observations.

3.1.15 Kernel fill

The extent of kernel filling in each selection was recorded as:

- i) Poor
- ii) Moderate
- iii) Well

3.4.16 Kernel plumpness

The plumpness of kernels in various selections was recorded as:

- i) Thin
- ii) Moderate
- iii) Plump

3.1.17 Ease of removal of kernel

On the basis of force required for removing kernel from the shell, various selections were categorised as:

- i) Very easy
- ii) Easy
- iii) Moderate
- vi) Difficult
- v) Very difficult

3.4.18 Shrivelled kernels

The percentage of shrivelled kernels was recorded from 25 randomly selected nuts.

3.5 CHEMICAL ANALYSIS

3.5.1 Kernel protein content

The Kjeldahl method as described by Kanwar and Chopra (1967) for estimation of crude protein in plant samples was followed and the procedure is as under:

One gram of dried kernel in each sample was taken in the Kjeldahl flask and digested in 20 ml concentrated sulphuric acid with approximately 2-3 g of digestion mixture. The latter constituted one part of trimixture (20 g copper sulphate + 1 g selenium powder + 3 g mercuric oxide) and 20 parts of potassium sulphate.

The digestion was continued till the material inside the flask attained a pale white or greenish yellow colour and allowed to cool. The digested material was then transferred to a 100 ml volumetric flask with 3-4 washings and final volume was made upto the mark. The contents were made homogenous by thorough mixing. Out of this

10 ml aliquot was then pipetted out and distilled with 10 ml NaOH solution (40%) in a microdistillation apparatus (Morkhan's apparatus) using 25 ml of 4 per cent boric acid solution and mixed indicator to trap the released ammonia which was estimated by titration with N/50 sulphuric acid. The nitrogen percentage so obtained was multiplied by a factor 5.3 suggested for tree nuts (Khanizadeh *et al.*, 1995) to calculate the crude protein percentage.

Mixed indicator

The mixed indicator was prepared by mixing methyl red (0.1 g) and bromocresol green (0.5 g) in 100 ml absolute alcohol and pH was adjusted to 4.5.

3.5.2 Kernel fat content

Fat content in the kernels was determined by following the method of Folch *et al.* (1957). The procedure is as under:

Extraction of total lipids

Two grams of oven dried kernels in each sample were crushed in pestle and mortar and extraction of lipids was carried out in 20 ml chloroform:methanol (2:1 v/v) solvent mixture. The contents were shaken for one hour on a shaker and kept overnight at 5°C in a refrigerator.

The above contents were filtered and transferred to a separating funnel. Then 0.9 per cent NaCl was added, whose quantity corresponded to 1/5th of the volume of above contents. The reaction mixture was shaken vigorously for 15 minutes and allowed the two layers to separate. Retained the lower layer in an already weighed glass container and evaporated it to dryness in hot waterbath.

Estimation

The difference between the weight of oil containing container and empty container represented the oil in 2 g of dried kernel sample and subsequently the oil percentage was calculated on dry weight basis.

3.6 STATISTICAL ANALYSIS

Standard procedures were followed to statistically analyse the data as suggested by Panse and Sukhatme (1985). The correlation and path analysis was carried out as per method suggested by Dewey and Lu (1959).

Chapter-4

EXPERIMENTAL RESULTS

EXPERIMENTAL RESULTS

The experimental results obtained in the present study are described under the following headings and subheadings:

4.1 FIELD SURVEYS

4.2 CHARACTERIZATION AND EVALUATION

4.2.1 Tree Characters

4.2.2 Foliage Characters

4.2.3 Floral and Fruiting Characters

4.2.4 Nut and Kernel Characters

4.3 CHEMICAL ANALYSIS

4.4 POMOLOGICAL DESCRIPTION OF WALNUT TREE SELECTIONS

4.5 CORRELATION STUDIES

4.6 PATH ANALYSIS

4.1 FIELD SURVEYS

A total of 342 trees of seedling origin growing scattered in Deedag (36), Chauras (70), Khal (52), Chikhria (103) and Gandoori (81) in district Sirmour were screened for growth, yield and quality characteristics. The preliminary observations and personal interaction with the owners of the trees resulted in identification of as many as 57 regular bearing trees exhibiting good nut and kernel characteristics. The above identified 57 trees were marked for comprehensive characterization and evaluation studies. the results obtained are presented as follows.

4.2 CHARACTERIZATION AND EVALUATION

The results pertaining to characterization and evaluation of 57 bearing persian walnut trees of seedling origin are presented under following sections:

4.2.1 Tree Characters

4.2.1.1 Trunk girth and trunk cross-sectional area: Minimum trunk girth (26.0 cm) and trunk cross-sectional area (53.82 cm^2) was recorded in SS-7 and maximum trunk girth (308.0 cm) and trunk cross sectional area (7546.80 cm^2) was recorded in SS-51. Mean values of trunk girth and trunk cross sectional area were recorded as 88.14 cm and 800.71 cm^2 with corresponding values of coefficient of variance to the extent of 61.72 and 154.41 per cent, respectively (Table 1).

4.2.1.2 Tree yield: Tree yield varied from 2.75 kg/tree (SS-47) to 60.5 kg/tree (SS-51). The mean and coefficient of variance were recorded as 17.55 kg/tree and 86.75 per cent, respectively (Table 1).

4.2.1.3 Yield efficiency: The extent of variation for yield efficiency ranged from 0.007 kg/cm^2 (SS-47) to 0.266 kg/cm^2 (SS-2) with 0.044 kg/cm^2 mean and 126.69 per cent coefficient of variance (Table 1).

4.2.1.4 Growth habit: Out of all 57 walnut trees of seedling origin, 33 trees were having spreading growth habit, 23 were semi-erect and one tree was having erect growth habit (Table 2 and Appendix-I).

4.2.1.5 Branching density: Data presented in Table 2 and Appendix-I showed that 37 trees were having dense branching density, 17 were having medium and three trees were having sparse branching density.

4.2.1.6 Shoot pubescence: Shoots of maximum trees (39) showed slight pubescence followed by glabrous shoot pubescence (17 trees) and shoots of one tree was pubescent in nature (Table 2 and Appendix-I).

Table 1. Extent of variation in tree characters (metric) of walnut trees of seedling origin in some villages of district Sirmour (H.P.)

Selection No.	Trunk girth (cm)	Trunk cross sectional area (cm ²)	Yield (kg/tree)	Yield efficiency (kg/cm ²)	Harvesting time	Number of nuts/tree
SS-1	52.00	215.27	4.50	0.019	8/8	513
SS-2	35.00	97.42	26.00	0.266	10/8	2150
SS-3	65.00	336.36	10.75	0.030	8/8	1125
SS-4	41.00	133.89	10.50	0.075	15/8	1055
SS-5	74.00	435.73	13.25	0.030	12/8	1462
SS-6	33.00	86.55	8.20	0.092	14/8	765
SS-7	26.00	53.82	4.75	0.074	14/8	328
SS-8	31.00	76.51	8.00	0.105	10/8	972
SS-9	56.50	254.16	14.00	0.055	16/8	1628
SS-10	53.00	223.67	19.50	0.085	12/8	1735
SS-11	53.00	223.67	10.50	0.045	12/8	1188
SS-12	43.00	147.34	8.50	0.054	14/8	1054
SS-13	72.00	412.38	16.00	0.039	10/8	1440
SS-14	64.00	326.05	7.00	0.022	22/8	845
SS-15	80.00	509.55	10.0	0.019	24/8	1346
SS-16	87.00	602.32	9.50	0.015	16/8	1265
SS-17	72.00	413.10	15.20	0.036	20/8	994
SS-18	72.00	413.10	18.00	0.044	21/8	1940
SS-19	91.00	659.30	29.00	0.044	29/8	2612
SS-20	90.00	644.80	14.50	0.022	29/8	1305
SS-21	81.50	529.03	8.20	0.015	15/8	926
SS-22	59.00	276.86	6.50	0.022	12/8	852
SS-23	173.00	2383.30	46.00	0.193	18/8	4415
SS-24	110.00	963.82	51.50	0.053	19/8	3705
SS-25	129.00	1324.70	18.00	0.014	21/8	1332
SS-26	152.00	1838.90	53.00	0.029	17/8	5505
SS-27	149.00	1768.20	42.50	0.024	16/8	4308
SS-28	82.00	535.57	11.50	0.021	12/8	932
SS-29	78.00	484.37	21.00	0.043	12/8	1065
SS-30	48.00	183.28	10.50	0.055	10/8	945
SS-31	52.00	215.27	22.00	0.102	14/8	2212
SS-32	78.00	484.37	14.50	0.029	12/8	1105
SS-33	73.00	423.98	7.00	0.017	12/8	864
SS-34	82.00	535.57	12.00	0.022	15/8	1738
SS-35	100.00	795.82	8.50	0.010	15/8	682
SS-36	89.00	630.50	9.00	0.014	4/8	632
SS-37	76.00	459.73	6.50	0.013	5/8	558
SS-38	58.00	268.09	5.50	0.019	20/8	658
SS-39	82.00	535.57	18.00	0.034	9/8	716
SS-40	89.00	630.48	37.00	0.059	20/8	3612
SS-41	89.50	637.62	9.50	0.014	20/8	776
SS-42	56.00	249.84	3.50	0.012	18/8	272
SS-43	47.00	175.68	4.50	0.023	20/8	608
SS-44	68.00	368.29	6.00	0.016	5/8	624
SS-45	49.00	191.04	5.50	0.026	12/8	465
SS-46	69.00	379.25	4.00	0.011	10/8	255
SS-47	59.00	276.86	2.75	0.007	10/8	234
SS-48	42.00	140.53	3.75	0.021	16/8	345
SS-49	64.00	326.05	6.00	0.018	12/8	682
SS-50	48.00	183.28	8.75	0.044	16/8	642
SS-51	308.00	7546.80	60.50	0.008	5/8	4608
SS-52	196.00	3056.60	40.50	0.013	2/8	3815
SS-53	220.00	3853.10	46.75	0.012	31/7	4808
SS-54	232.00	4275.50	49.00	0.011	2/8	3916
SS-55	180.00	2577.40	50.50	0.019	2/8	3624
SS-56	109.00	946.30	11.75	0.012	30/8	984
SS-57	156.50	1950.00	20.50	0.010	1/9	1224
Mean	88.14	800.71	17.55	0.044		1585.37
S.D.	54.40	1236.36	15.22	0.056		1333.96
Covariance (%)	61.72	154.41	86.75	126.69		84.14

SS - Sirmour Selection

Table 2: Extent of variation in tree characters (non-metric) of walnut trees of seedling origin in some villages of district Sirmour (H.P.)

Character Extent of variation	Growth habit			Branching density			Shoot pubescence			Shoot colour		
	Spreading	Semi-erect	Erect	Sparse	Medium	Dense	Glabrous	Slightly pubescent	Pubescent	Green brown	Blackish	Pale brown
Frequency (number of trees)	33	23	1	3	17	37	17	39	1	32	20	5
Percentage (%)	57.90	40.35	1.75	5.26	29.82	64.91	29.83	68.42	1.75	56.14	35.09	8.77

4.2.2.7 Leaf and rachis pubescence: Leaf and rachis of 41 trees were slightly pubescent, 13 were glabrous and only three were pubescent in nature (Table 4 and Appendix-I).

4.2.2.8 Leaf and/or rachis persistence: Frequency for a few leaves remain attached and intermediate for leaf and/or rachis persistence was 33 and 24, respectively (Table 4 and Appendix-I).

4.2.2.9 Leafing time: The earliest leaf bud burst was recorded on 19th March in SS-35 and SS-36 followed by SS-13, SS-16, SS-44 on 20th March. Whereas SS-56 was the last to show leaf bud burst on 13th April preceded by SS-57 on 12th April (Table 3).

4.2.2.10 Leaf fall: The earliest date of leaf fall was recorded on 21st August in SS-37 followed by SS-35 on 22nd August. SS-56 was the last to show leaf fall on 22nd September preceded by SS-57 on 20th September (Table 3).

4.2.3 Floral and Fruiting Characters

4.2.3.1 First male bloom date: The first male bloom date was recorded earliest in SS-1 on 23rd March immediately followed by SS-35, SS-44 and SS-53 on 24th March. Whereas SS-56 and SS-57 were last to show first male flowering on 14th April preceded by SS-14 on 13th April (Table 5).

4.2.3.2 Last male bloom date: End of male flowering date was earliest in SS-1 on 3rd April followed by SS-35, SS-44 and SS-45 on 4th April, while, SS-20, SS-25, SS-56 and SS-57 were last to show end of male flowering on 21st April preceded by SS-14 and SS-15 on 20th April (Table 5).

4.2.3.3 First female bloom date: The earliest date for first female bloom date was observed in SS-53 on 28th March followed by SS-1 on 29th March. Whereas SS-57 was last to show first female bloom date on 20th April preceded by SS-56 and SS-20 on 19th April (Table 5).

Table 3. Extent of variation in foliage characters (metric) of walnut trees of seedling origin in some villages of district Sirmour (H.P.)

Selection No.	Leafing time	Leaf length (cm)	Leaf width (cm)	No. of leaflets	Leaflet width (cm)	Time of leaf fall
SS-1	30/3	29.00	21.00	8.3	4.3	2/9
SS-2	1/4	36.50	21.00	8.0	4.4	15/9
SS-3	1/4	29.00	21.50	7.3	5.1	13/9
SS-4	22/3	22.90	18.10	7.7	5.1	15/9
SS-5	22/3	22.10	17.10	8.0	3.2	15/9
SS-6	25/3	24.00	21.90	7.0	2.7	12/9
SS-7	5/4	30.70	14.60	8.7	4.4	1/9
SS-8	25/3	32.50	21.60	7.3	4.0	6/9
SS-9	4/4	25.70	16.90	6.7	4.2	3/9
SS-10	29/3	27.30	12.40	7.0	4.2	14/9
SS-11	28/3	34.50	28.20	8.3	4.6	12/9
SS-12	28/3	38.90	25.50	7.0	5.4	10/9
SS-13	20/3	32.50	20.00	7.3	5.0	14/9
SS-14	10/4	29.80	23.20	7.7	4.6	16/9
SS-15	8/4	21.60	15.60	6.3	4.3	9/9
SS-16	20/3	32.70	21.40	8.2	2.9	26/8
SS-17	31/3	41.80	23.50	8.7	6.7	12/9
SS-18	31/3	34.50	26.20	10.0	6.2	15/9
SS-19	3/4	35.50	27.10	8.0	5.4	16/9
SS-20	5/4	34.90	24.60	7.6	5.1	18/9
SS-21	21/3	34.60	20.80	7.3	4.5	25/8
SS-22	27/3	40.00	11.50	9.2	5.0	30/8
SS-23	2/4	28.00	22.90	7.2	4.2	4/9
SS-24	30/3	37.20	25.60	7.7	7.0	2/9
SS-25	4/4	38.20	21.90	6.7	7.1	4/9
SS-26	25/3	38.50	27.10	7.3	5.0	12/9
SS-27	26/3	30.50	22.50	7.7	4.4	15/9
SS-28	4/4	31.30	19.10	6.7	5.5	16/9
SS-29	30/3	25.70	19.30	7.3	5.9	29/8
SS-30	27/3	26.10	17.40	7.0	4.0	27/8
SS-31	1/4	26.80	22.20	5.5	4.9	9/7
SS-32	2/4	33.20	20.50	9.2	5.4	7/9
SS-33	3/4	30.00	19.60	8.7	4.3	12/9
SS-34	26/3	33.40	23.10	9.2	5.0	1/9
SS-35	19/3	45.50	29.60	9.2	6.5	22/8
SS-36	19/3	33.00	21.20	8.7	4.0	24/8
SS-37	24/3	31.50	23.40	7.3	6.4	21/8
SS-38	31/3	30.00	18.90	9.2	4.0	12/9
SS-39	26/3	33.00	21.70	7.7	4.8	3/9
SS-40	26/3	30.20	21.10	7.3	5.5	3/9
SS-41	2/4	32.80	24.60	6.7	4.9	11/9
SS-42	3/4	34.30	24.60	7.3	7.4	12/9
SS-43	5/4	35.80	25.60	8.0	6.1	15/9
SS-44	20/3	35.20	24.70	9.2	6.2	10/9
SS-45	31/3	38.50	26.20	7.0	6.0	8/9
SS-46	26/3	35.40	23.00	8.7	4.4	11/9
SS-47	5/4	32.00	20.90	7.3	4.5	12/9
SS-48	27/3	36.20	20.50	7.7	5.2	28/8
SS-49	3/4	34.50	19.20	7.0	4.5	9/9
SS-50	29/3	28.60	18.40	9.2	4.4	12/9
SS-51	7/4	31.50	24.50	6.7	5.5	18/9
SS-52	21/3	29.40	21.20	7.0	4.7	12/9
SS-53	29/3	40.20	20.60	9.2	4.7	15/9
SS-54	29/3	36.20	25.80	7.3	5.2	12/9
SS-55	29/3	31.80	24.10	7.7	5.4	14/9
SS-56	13/4	36.90	18.90	8.7	5.1	22/9
SS-57	12/4	40.80	19.50	7.3	4.9	20/9
Mean		32.69	21.63	7.77	4.99	
S.D		4.99	3.62	0.86	0.96	
Covariance (%)		15.28	16.72	11.01	19.17	

SS - Sirmour Selection

Table 4: Extent of variation in foliage characters (non-metric) of walnut trees of seedling origin in some villages of district Sirmour (H.P.)

Character Extent of variation	Leaf colour			Rachis colour			Leaf and rachis pubescence			Leaf and rachis persistence	
	Dark Green	Green	Light Green	Yellow	Green	Red	Pubescent	Slightly pubescent	Glabrous	Few remain attached	Intermediate
Frequency (number of trees)	20	30	7	14	33	10	3	41	13	33	24
Percentage (%)	35.09	52.63	12.28	24.56	57.90	17.54	5.26	71.93	22.81	57.89	42.11

4.2.3.4 Last female bloom date: End of female bloom date was earliest in SS-1 on 5th April and SS-14 and SS-57 were last to show end of female bloom on 27th April preceded by SS-20 and SS-56 on 26th April (Table 5).

4.2.3.5 Duration of male bloom: The minimum duration of male bloom (7 days) was recorded in SS-12, SS-33 and SS-37 followed by 8 days in SS-7, SS-9, SS-11, SS-14, SS-39, SS-47, SS-56 and SS-57. Whereas maximum duration of male bloom (16 days) was recorded in SS-53 preceded by 15 days in SS-22, SS-51 and SS-54. Mean and covariance values were recorded as 11.21 days and 20.45 per cent, respectively (Table 5).

4.2.3.7 Duration of female bloom: The perusal of data from Table 5 showed that minimum duration of female bloom (6 days) was observed in SS-35 followed by 7 days in SS-12, SS-15, SS-19, SS-25, SS-28 and SS-33. Whereas maximum duration of female bloom (15 days) in SS-8, SS-46, SS-51 and SS-54 preceded by 14 days in SS-38 and SS-53. Mean and covariance values were recorded as 10.39 days and 22.58 per cent, respectively (Table 5).

4.2.3.8 Degree of dichogamy: The extent of variation for degree of dichogamy ranged from 10 per cent (SS-24) to 100 per cent (SS-19, SS-33, SS-35, SS-45 and SS-46). Mean and covariance values for degree of dichogamy were recorded as 59.89 per cent and 43.49 per cent, respectively (Table 5).

4.2.3.9 Nature of dichogamy: The data presented in Table 6 and Appendix-II depicted that out of all 57 walnut trees of seedling origin, 48 were protandrous in nature and nine were homogamous in nature.

4.2.3.10 Bearing habit: No variation was observed for bearing habit and all 57 trees exhibited terminal bearing habit (Table 6 and Appendix-II).

4.2.3.11 Female flower abundance: Light, intermediate and heavy female flower abundance was observed in 16, 31 and 10 trees, respectively (Table 6 and Appendix-II).

4.2.3.12 Stigma colour: Colour of stigma in pistillate flowers was recorded as yellow in 31 trees, red in 21 trees and green in 5 trees (Table 6 and Appendix-II).

4.2.3.13 Hull persistence after nut fall: The perusal of data from Table 6 and Appendix-II depicted that hull of nuts in 39 trees showed slight persistence after nut fall while in 18 trees, moderate hull persistence after nut fall was recorded.

4.2.3.14 Hull dehiscence: The data presented in Table 6 and Appendix-II showed that nuts of 43 trees were dehiscent in nature followed by slightly dehiscent nature of nuts in 14 trees. Indehiscent nature of hull dehiscence was not seen in any of the trees selected.

4.2.4 Nut and Kernel Characters

4.2.4.1 Nut shape: The data for nut shape through suture and nut shape perpendicular to suture is presented in Table 8 a and Appendix-III.

4.2.4.1.1 Nut shape through suture: Nut shape through suture was circular, ovate, elliptic, trapezoid, broad elliptic and triangular in 17, 18, 19, 5, 4, and 3 trees, respectively (Fig.5). Only one selection (SS-20) produced obovate nuts (Table 8a and Appendix-III).

4.2.4.1.2 Nut shape perpendicular to suture: Nut shape perpendicular to suture was (Fig 6) circular in maximum number of trees (23), followed by trapezoid in 16, ovate in 8, elliptic in 6, obovate in 3 and cordate in only one tree (Table 8a and Appendix-III).

4.2.4.2 Nut diameter (Fig.7): The extent of variation for nut diameter through suture ranged from 23.83 mm (SS-11) followed by 23.93 mm in SS-15 to 34.97 mm (SS-26) preceded by 34.79 mm in SS-23. Whereas nut diameter perpendicular to suture was minimum (24.48 mm) in SS-11 and maximum (37.89 mm) in SS-53. Mean values for nut diameter through suture and nut diameter perpendicular to suture were 29.76 mm

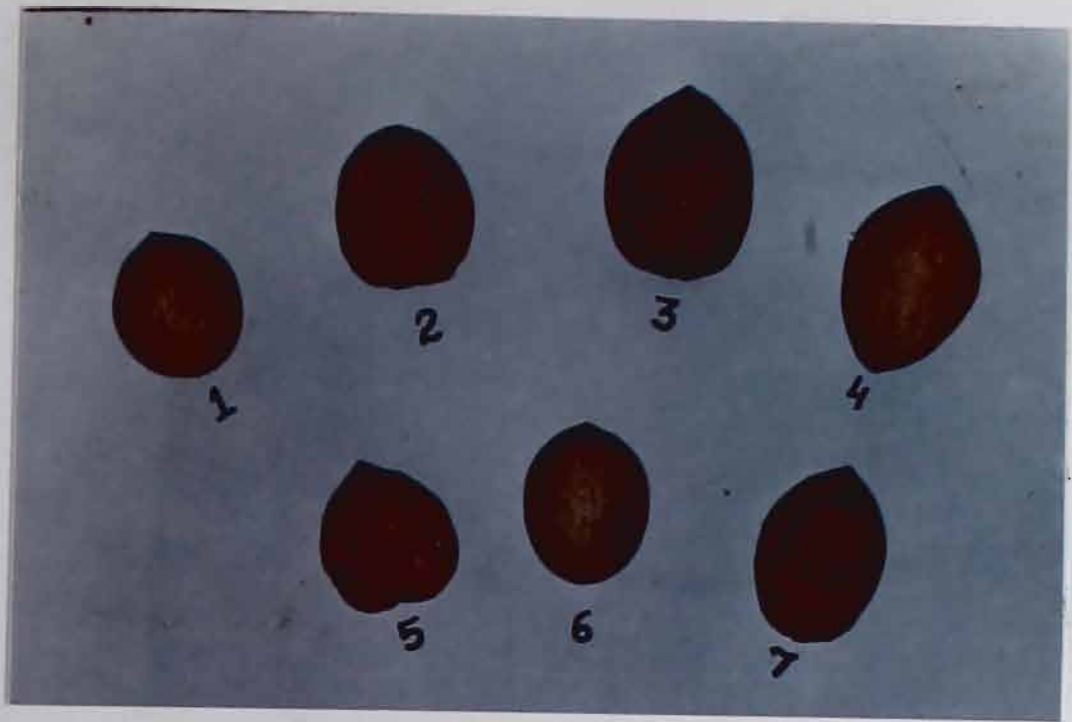


Fig. 5: Variation in nut shape through suture

- | | | | |
|--------------|-------------|-------------------|------------|
| 1. Circular | 3. Ovate | 5. Triangular | 7. Obovate |
| 2. Trapezoid | 4. Elliptic | 6. Broad elliptic | |

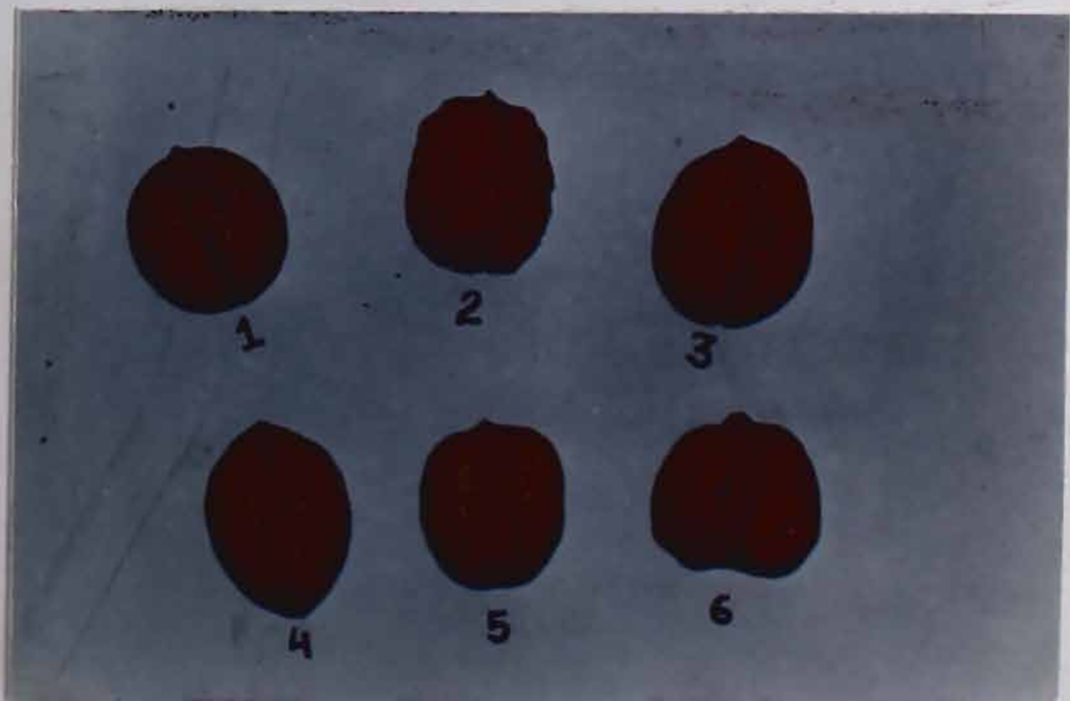


Fig. 6 : Variation in nut shape perpendicular to suture

- | | | |
|--------------|-------------|------------|
| 1. Circular | 3. Ovate | 5. Obovate |
| 2. Trapezoid | 4. Elliptic | 6. Cordate |

Table 5. Extent of variation in flowering characters (metric) of walnut trees of seedling origin in some villages of district Sirmour (H.P.)

Selection No.	First male bloom date	Last male bloom date	First female bloom date	Last female bloom date	Duration of male bloom (days)	Duration of female bloom (days)	Degree of dichogamy (%)
SS-1	23/3	3/4	29/3	5/4	12	8	25.00
SS-2	2/4	10/4	9/4	20/4	9	12	83.33
SS-3	2/4	13/4	5/4	17/4	12	13	30.77
SS-4	29/3	9/4	7/4	18/4	12	12	75.00
SS-5	28/3	7/4	4/4	16/4	11	13	69.23
SS-6	31/3	8/4	6/4	16/4	9	11	72.73
SS-7	8/4	15/4	13/4	21/4	8	9	66.67
SS-8	31/3	8/4	6/4	20/4	9	15	80.00
SS-9	6/4	13/4	10/4	18/4	8	11	63.64
SS-10	31/3	11/4	4/4	14/4	12	11	27.27
SS-11	31/3	7/4	5/4	14/4	8	10	70.00
SS-12	31/3	6/4	5/4	11/4	7	7	71.43
SS-13	28/3	8/4	1/4	10/4	12	10	20.00
SS-14	13/4	20/4	16/4	27/4	8	12	58.33
SS-15	11/4	20/4	16/4	22/4	10	7	28.57
SS-16	29/3	9/4	5/4	15/4	12	11	54.55
SS-17	3/4	13/4	8/4	19/4	11	12	50.00
SS-18	4/4	16/4	9/4	18/4	13	10	20.00
SS-19	6/4	16/4	18/4	24/4	11	7	100.00
SS-20	11/4	21/4	19/4	26/4	11	8	62.50
SS-21	30/3	10/4	9/4	16/4	12	8	75.00
SS-22	29/3	12/4	8/4	19/4	15	12	58.33
SS-23	3/4	14/4	9/4	17/4	12	9	33.33
SS-24	4/4	16/4	8/4	17/4	13	10	10.00
SS-25	10/4	21/4	9/4	25/4	12	7	57.14
SS-26	31/3	13/4	5/4	15/4	14	11	18.18
SS-27	31/3	12/4	5/4	15/4	13	11	27.27
SS-28	1/4	10/4	9/4	15/4	11	7	71.43
SS-29	4/4	14/4	12/4	21/4	11	10	70.00
SS-30	1/4	10/4	9/4	19/4	11	11	81.82
SS-31	3/4	12/4	9/4	19/4	10	12	66.67
SS-32	30/3	9/4	8/4	17/4	11	10	80.00
SS-33	4/4	10/4	11/4	18/4	7	7	100.00
SS-34	31/3	11/4	9/4	17/4	12	9	66.67
SS-35	24/3	4/4	9/4	14/4	12	6	100.00
SS-36	25/3	6/4	6/4	16/4	13	11	90.91
SS-37	31/3	6/4	5/4	12/4	7	8	75.00
SS-38	4/4	17/4	14/4	23/4	14	10	60.00
SS-39	29/3	5/4	4/4	17/4	8	14	85.71
SS-40	29/3	10/4	8/4	17/4	14	10	70.00
SS-41	29/3	8/4	6/4	14/4	12	9	66.67
SS-42	31/3	11/4	9/4	16/4	12	8	62.50
SS-43	1/4	11/4	9/4	17/4	11	9	66.67
SS-44	24/3	4/4	4/4	12/4	12	9	88.89
SS-45	26/3	4/4	9/4	19/4	10	11	100.00
SS-46	28/3	6/4	8/4	22/4	10	15	100.00
SS-47	31/3	7/4	7/4	19/4	8	13	92.31
SS-48	31/3	9/4	8/4	15/4	10	8	75.00
SS-49	31/3	13/4	7/4	19/4	14	12	41.67
SS-50	28/3	8/4	6/4	15/4	12	10	70.00
SS-51	1/4	15/4	3/4	17/4	15	15	13.33
SS-52	29/3	11/4	2/4	14/4	14	13	23.08
SS-53	24/3	8/4	28/3	10/4	16	14	14.29
SS-54	28/3	11/4	31/3	14/4	15	15	20.00
SS-55	28/3	10/4	31/3	12/4	14	13	15.38
SS-56	14/4	21/4	19/4	26/4	8	8	62.50
SS-57	14/4	21/4	20/4	27/4	8	8	75.00
Mean					11.21	10.39	59.89
S.D.					2.29	2.35	26.05
Covariance(%)					20.45	22.58	43.49

SS Sirmour Selection

Table 6: Extent of variation in flowering characters (non-metric) of walnut trees of seedling origin in some villages of district Sirmour (H.P.)

Character Extent of variation	Nature of dichogamy		Bearing habit	Female flower abundance			Stigma colour			Hull persistence after nut fall		Hull dehiscence	
	Homogamous	Protandrous	Terminal	Light	Intermediate	Heavy	Yellow	Green	Red	Slight	Moderate	Dehiscent	Slightly dehiscent
Frequency (number of trees)	9	48	57	16	31	10	31	5	21	39	18	43	14
Percentage (%)	15.78	84.20	100	28.07	54.39	17.54	54.39	8.77	36.84	68.42	31.58	75.44	24.56

and 31.34 mm, respectively with corresponding values of covariance as 8.66 and 9.27 per cent (Table 7).

4.2.4.3 Nut length (Fig.7): Minimum nut length (26.27 mm) was recorded in SS-27 and maximum (44.08 mm) was in SS-52. Mean and covariance values for nut length were recorded as 34.39 mm and 12.45 per cent, respectively (Table 8a).

4.2.4.4 Shell texture (Fig.7): Shell texture was observed as smooth, intermediate, rough and very rough in nuts of three, 28, 19 and seven trees, respectively (Table 8a and Appendix-III).

4.2.4.5 Shell colour: Colour of shell of nuts was observed to be very light in two trees, light in 19 trees, medium in 25 trees, dark in 9 trees and very dark in two trees (Table 8b and Appendix-III).

4.2.4.6 Shell seal: Data presented in Table 8b Appendix-III depicted that nuts of maximum trees (32) were having strong shell seal followed by medium shell seal (18 trees) and weak shell seal in seven trees.

4.2.4.7 Shell strength: The perusal of data from Table 8b and Appendix-III showed that shell strength varied from strong, medium and weak in 38, 16 and three trees, respectively.

4.2.4.8 Shell integrity: No variation was recorded for shell integrity and nuts of all the 57 selected trees showed complete shell integrity (Table 8b and Appendix-III).

4.2.4.9 Shell thickness: The perusal of data from Table 7 showed that shell thickness varied from 1.61 mm (SS-12) to 3.02 mm (SS-43). Mean and covariance values were recorded as 2.16 mm and 15.33 per cent, respectively.

4.2.4.10 In-shell nut weight: The lowest in-shell nut weight was observed in SS-43 (6.75 g) and highest in SS-57 (16.1 g). Mean and covariance values were recorded as 10.69 g and 20.59 per cent, respectively (Table 7).

4.2.4.11 Kernel colour (Fig.8): Colour of kernels was observed to be very light brown, light brown, medium and dark brown in 2, 22, 20 and 13 trees, respectively (Table 8c and Appendix-III).

4.2.4.12 Kernel percentage: The minimum kernel percentage (28.64%) was observed in SS-28 followed by 28.89 per cent in SS-1 and maximum kernel percentage (53.55%) was observed in SS-49. Mean and covariance values were recorded as 40.58 per cent and 11.99 per cent, respectively (Table 7).

4.2.4.13 Kernel weight: Kernel weight varied from 2.26 g (SS-1) followed by 2.65 g (SS-11) to 6.8 g in SS-51 preceded by 6.6 g in SS-17 (Table 7). Mean and covariance values were 4.35 g and 24.99 per cent, respectively.

4.2.4.14 Kernel veins: The percentage of kernel veins was 5.0, 10.0, 20.0 and 40.0 in 7, 23, 24 and 3 trees, respectively (Table 7), with 15.02 per cent mean and 55.23 per cent covariance.

4.2.4.15 Kernel fill: Moderately and well filled kernels were observed in 15 and 41 trees, respectively with only SS-20 having thirty filled kernels (Table 8c and Appendix-III).

4.2.4.16 Kernel plumpness: Kernels of 33 trees showed moderate plumpness whereas, thin plumpness was observed in 24 trees (Table 8c and Appendix-III).

4.2.4.17 Ease of removal of kernel halves: Data from Table 8c and Appendix-III depicted that nuts of 31 trees were having moderate kernel removal followed by 15, nine and two trees having easy, difficult and very difficult kernel removal, respectively.

4.2.4.18 Kernel shrivel: As many as 26 trees produced nuts with shrivelled kernels varying between 5 and 30 per cent (Table 7). The remaining 31 trees, exhibited no shrivelled kernels in their nuts. Mean and covariance values were recorded as 7.28 per cent and 135.57 per cent, respectively (Table 7).



Fig. 7: Variation in nut size and shell texture



Fig. 8: Variation in kernel colour

4.3 CHEMICAL ANALYSIS

4.3.1 Kernel Protein

The perusal of data from Table 7 showed that protein percentage varied 9.00 per cent in SS-8 to 17.36 per cent in SS-56. Mean and covariance values were recorded as 11.97 per cent and 12.14 per cent, respectively.

4.3.2 Kernel Fat

The minimum fat percentage (32.70%) was observed in SS-54 and maximum (68.70%) in SS-43. Mean and covariance values for kernel fat were recorded as 50.28 per cent and 13.55 per cent, respectively (Table 7).

4.4 POMOLOGICAL DESCRIPTION OF WALNUT TREE SELECTIONS

The pomological description of all the 57 selected walnut trees of seedling origin is given as under:

SS-1

Tree semi-erect; branching medium; yield (4.50 kg/tree); yield efficiency (0.019 kg/cm²). Protandrous; terminal bearer; slight hull persistence after nut fall; leafing time (30th March). Nut circular in shape both through suture and perpendicular to suture; shell texture medium; shell colour light; shell seal intermediate; shell thickness (1.80 mm); nut weight (8.70 g); moderate kernel removal; kernel percentage (28.89%); kernel fill moderate; kernel veins (10%); kernel colour medium; kernel protein (10.91%) and kernel fat (50.50%).

SS-2

Tree semi-erect; branching sparse; yield (26.00 kg/tree); yield efficiency (0.266 kg/cm²). Protandrous, dichogamy (83.33%); terminal bearer; slight hull persistence after nut fall; leafing time (1st April). Nut circular in shape through suture

as well as perpendicular to suture; shell texture smooth; shell colour medium; shell seal strong, shell thickness (2.24 mm); nut weight (11.05 g); moderate kernel removal; kernel percentage (46.25%); kernel fill well; kernel veins (20%); kernel colour medium; kernel percentage (45.25%); kernel protein (12.69%) and kernel fat (46.40%).

SS-3

Tree semi-erect; branching dense; yield (10.75 kg/tree); yield efficiency (0.030 kg/cm²). Protandrous; terminal bearer; slight hull persistence after nut fall; leafing time (1st April). Nut ovate in shape through suture; nut trapezoid in shape perpendicular to suture; shell texture intermediate; shell colour light; shell seal strong; shell thickness (2.06 mm); nut weight (8.70 g); easy kernel removal; kernel fill well; kernel veins (20%); kernel colour medium; kernel percentage (43.10%), kernel protein (10.29%) and kernel fat (59.85%).

SS-4

Tree spreading; branching dense; yield (10.50 kg/tree); yield efficiency (0.075 kg/cm²). Protandrous; terminal bearer; slight hull persistence after nut fall; leafing time (22nd March). Nut circular in shape through suture and ovate in shape perpendicular to suture; shell texture medium; shell colour medium; shell seal weak; shell thickness (2.21 mm); nut weight (9.50 g); moderate kernel removal; kernel percentage (35.79%); kernel fill well; kernel veins (10%); kernel colour dark; kernel protein (14.54%) and kernel fat (46.50%).

SS-5

Tree semi-erect; branching dense; yield (13.25 kg/tree); yield efficiency (0.030 kg/cm²). Protandrous; terminal bearer; moderate hull persistence after nut fall; leafing time (22nd March). Nut elliptic in shape through suture and circular in shape perpendicular to suture; shell texture medium; shell colour medium; shell seal strong; shell thickness (1.75 mm); nut weight (10.30 g); moderate kernel removal; kernel

Table 7. Extent of variation in nut and kernel characters (metric) of walnut trees of seedling origin in some villages of district Sirmour (H.P.)

Selection No.	Nut diameter (mm)		Nut length (mm)	Shell thickness (mm)	In shell nut weight (g)	Kernel percentage	Kernel weight (g)	Kernel veins (%)	Shrivalled kernel (%)	Protein (%)	Fat (%)
	through suture	perpendicular to suture									
SS-1	27.87	26.72	30.36	1.80	8.70	28.89	2.26	10	0	10.91	50.50
SS-2	31.37	32.79	35.49	2.24	11.05	45.25	5.00	20	15	12.69	46.40
SS-3	32.15	31.26	36.40	2.06	8.70	43.10	3.75	20	25	10.29	59.85
SS-4	28.20	31.98	36.10	2.21	9.50	35.79	3.40	10	30	14.54	46.50
SS-5	29.00	29.21	33.89	1.75	10.30	41.75	4.30	5	5	12.58	50.40
SS-6	31.45	30.29	33.38	2.24	10.95	44.29	4.86	5	0	13.39	44.85
SS-7	29.46	33.65	35.73	1.89	11.55	42.86	4.95	20	0	14.69	47.00
SS-8	27.25	28.50	31.29	1.97	9.65	31.09	3.00	5	0	9.00	57.10
SS-9	26.35	30.75	30.14	1.71	8.60	38.95	3.35	20	30	11.87	54.45
SS-10	27.77	30.78	35.09	1.90	10.75	43.72	4.70	20	10	12.02	43.80
SS-11	23.83	24.48	28.36	2.08	8.50	31.18	2.65	10	0	10.65	54.45
SS-12	25.73	26.35	29.84	1.61	7.80	38.46	3.00	10	20	12.65	41.85
SS-13	27.94	31.96	31.48	2.56	11.30	42.04	4.75	10	0	11.21	53.45
SS-14	28.53	28.34	29.46	1.98	8.30	39.76	3.30	10	0	11.17	51.80
SS-15	23.93	29.85	28.04	2.04	7.40	39.19	2.90	20	0	12.65	46.95
SS-16	25.93	29.36	30.72	1.69	7.05	43.26	3.05	20	0	11.72	47.45
SS-17	30.25	33.89	41.39	2.24	15.25	43.28	6.60	20	0	12.10	48.45
SS-18	29.23	28.81	34.11	1.96	9.05	37.57	3.40	10	10	11.39	48.05
SS-19	31.28	32.63	32.01	2.23	11.85	43.88	5.20	40	0	12.32	42.05
SS-20	28.35	31.20	34.79	2.59	10.75	41.86	4.50	10	0	11.99	54.75
SS-21	25.84	25.29	31.75	2.23	8.50	36.47	3.10	10	10	10.43	51.35
SS-22	27.83	26.35	30.65	2.09	7.30	37.67	2.75	10	0	11.26	51.25
SS-23	34.79	33.14	39.36	1.99	10.00	38.00	3.80	20	0	11.58	49.90
SS-24	33.94	35.64	36.29	1.98	12.90	39.15	5.05	20	15	11.32	49.35
SS-25	34.97	34.89	30.45	2.19	12.95	37.07	4.80	10	10	12.20	47.45
SS-26	26.24	26.71	29.26	1.97	9.60	44.27	4.25	5	0	12.17	39.75
SS-27	30.85	31.64	26.27	2.05	9.40	40.43	3.80	10	0	10.95	50.25
SS-28	29.92	33.72	38.26	2.13	11.00	28.64	3.15	20	0	11.99	49.45
SS-29	29.36	29.84	42.17	2.86	10.90	43.58	4.75	20	0	10.84	52.95
SS-30	29.85	30.45	30.49	2.59	10.55	44.55	4.70	10	0	10.61	53.30
SS-31	28.26	28.43	32.00	1.86	9.90	45.96	4.55	10	0	9.89	52.40
SS-32	29.16	31.84	32.24	2.57	13.75	40.00	5.50	10	0	10.06	53.60
SS-33	29.83	31.86	36.62	1.71	8.70	42.53	3.70	5	10	10.83	64.35
SS-34	29.70	30.39	32.71	2.02	10.20	37.25	3.80	10	20	11.80	53.20
SS-35	32.50	35.21	33.62	1.72	13.05	39.08	5.10	20	0	12.85	60.45
SS-36	34.47	35.86	40.03	2.07	14.30	40.56	5.80	20	0	13.69	47.50
SS-37	29.64	30.68	33.53	2.12	10.95	40.18	4.40	20	10	12.19	53.45
SS-38	30.16	31.93	34.45	1.92	8.20	47.56	3.90	40	30	10.65	62.20
SS-39	29.99	35.45	31.65	2.36	12.65	33.60	4.25	20	0	14.29	39.65
SS-40	28.69	30.01	36.58	2.15	9.75	45.13	4.40	20	25	11.50	51.05
SS-41	30.46	32.14	34.27	1.94	12.30	41.87	5.15	10	0	12.65	45.95
SS-42	29.83	34.47	31.49	2.25	12.40	37.50	4.65	5	5	14.25	43.30
SS-43	25.82	27.62	33.82	3.02	6.75	40.74	2.75	20	15	12.92	68.70
SS-44	29.74	30.79	28.13	1.92	9.30	47.31	4.40	40	10	12.32	50.25
SS-45	29.74	30.79	33.43	2.36	10.05	39.80	4.00	20	5	11.13	47.00
SS-46	32.44	35.97	37.65	2.07	14.45	42.91	6.20	20	5	9.94	54.60
SS-47	29.41	31.18	32.11	2.24	8.80	40.34	3.55	20	30	11.80	52.66
SS-48	28.39	29.29	28.98	2.65	9.00	30.56	2.75	10	25	12.09	47.15
SS-49	30.13	31.24	39.69	2.09	9.15	53.55	4.90	20	5	14.76	36.80
SS-50	29.10	29.84	37.83	2.04	11.70	38.89	4.55	5	20	10.09	58.40
SS-51	32.80	36.14	37.57	2.17	14.65	46.42	6.80	20	0	12.71	66.50
SS-52	33.38	32.77	44.08	2.22	13.20	45.83	6.05	10	0	11.48	41.20
SS-53	32.64	37.89	43.12	2.26	11.35	47.14	5.35	10	0	11.25	53.25
SS-54	31.89	33.61	36.76	2.88	13.65	44.69	6.10	10	20	13.58	32.70
SS-55	32.15	32.52	43.09	2.03	14.00	44.64	6.25	20	0	12.39	50.75
SS-56	32.59	33.48	40.88	1.96	11.15	35.53	3.80	10	0	17.36	39.55
SS-57	34.17	34.92	40.88	2.98	16.10	38.51	6.20	10	0	10.54	54.65
Mean	29.76	31.34	34.39	2.16	10.69	40.58	4.35	15.02	7.28	11.97	50.28
S.D	2.58	2.91	4.28	0.33	2.20	4.86	1.09	8.29	9.87	1.45	6.89
Covariance(%)	8.66	9.27	12.45	15.33	20.59	11.99	24.99	55.23	135.57	12.14	13.55

SS - Sirmour Selection

Table 8(a) : Extent of variation in nut characters (non-metric) of walnut trees of seedling origin in some villages of district Sirmour (H.P.)

Character Extent of variation	Nutshape through suture							Nut shape perpendicular to suture					
	Circular	Trapezoid	Ovate	Elliptic	Triangular	Broad elliptic	Obovate	Circular	Trapezoid	Ovate	Elliptic	Obovate	Cordate
Frequency (number of trees)	17	5	18	9	3	4	1	23	16	8	6	3	1
Percentage (%)	29.83	8.77	31.58	15.79	5.26	7.02	1.75	40.35	28.07	14.04	10.53	5.26	1.75

Table 8(b) : Extent of variation in nut characters (non-metric) of walnut trees of seedling origin in some villages of district Sirmour (H.P.)

Character Extent of variation	Shell colour					Shell strength			Shell integrity	Shell texture				Shell seal		
	Very light	Light	Medium	Dark	Very dark	Strong	Medium	Weak	Complete	Smooth	Intermediate	Rough	Very rough	Strong	Medium	Weak
Frequency (number of trees)	2	19	25	9	2	38	16	3	57	3	28	19	7	32	18	7
Percentage (%)	3.51	33.33	43.86	15.79	3.51	66.67	28.07	5.26	100	5.26	49.12	33.33	12.28	56.14	31.58	12.28

Table 8(c) : Extent of variation in kernel characters (non-metric) of walnut trees of seedling origin in some villages of district Sirmour (H.P.)

Character Extent of variation	Kernel colour				Kernel fill			Kernel plumpness		Ease of removal of kernel halves			
	Dark	Medium	Light	Very light	Well	Moderate	Thin	Moderate	Thin	Easy	Moderate	Difficult	Very difficult
Frequency (number of trees)	13	20	22	2	41	15	1	33	24	15	31	9	2
Percentage (%)	22.81	35.09	38.59	3.51	71.93	26.32	1.75	57.90	42.10	26.32	54.39	15.79	3.50

percentage (41.75%); kernel fill well; kernel veins (5%); kernel colour dark; kernel protein (12.58%) and kernel fat (46.50%).

SS-6

Tree semi-erect; branching dense; yield (8.20 kg/tree); yield efficiency (0.092 kg/cm²). Protandrous; terminal bearer; moderate hull persistence after nut fall; leafing time (25th March). Nut circular in shape both through suture and perpendicular to suture; shell texture rough; shell colour medium; shell seal intermediate; shell thickness (2.24 mm); nut weight (10.95 g); easy kernel removal; kernel percentage (44.29%); kernel fill well; kernel veins (5%); kernel colour light; kernel protein (13.39%) and kernel fat (44.85%).

SS-7

Tree erect; branching sparse; yield (4.75 kg/tree); yield efficiency (0.074 kg/cm²). Protandrous; terminal bearer; slight hull persistence after nut fall; leafing time (5th April). Nut elliptic in shape through suture and circular in shape perpendicular to suture; shell texture medium; shell colour light; shell seal strong; shell thickness (1.89 mm); nut weight (11.55 g); moderate kernel removal; kernel percentage (42.86%); kernel fill well; kernel veins (20%); kernel colour dark; kernel protein (14.69%) and kernel fat (47.00%).

SS-8

Tree spreading; branching dense; yield (8.00 kg/tree); yield efficiency (0.105 kg/cm²). Protandrous; terminal bearer; slight hull persistence after nut fall; leafing time (25th March). Nut circular in shape both through suture and perpendicular to suture; shell texture medium; shell colour medium; shell seal strong; shell thickness (1.97 mm); nut weight (9.65 g); difficult kernel removal; kernel percentage (31.09%); kernel fill moderate; kernel veins (5%); kernel colour very light; kernel protein (9.00%) and kernel fat (57.10%).

SS-9

Tree semi-erect; branching medium; yield (14.0 kg/tree); yield efficiency (0.055 kg/cm²). Protandrous; terminal bearer; slight hull persistence after nut fall; leafing time (4th April). Nut circular in shape both through suture and perpendicular to suture; shell texture rough; shell colour medium; shell seal intermediate; shell thickness (1.71 mm); nut weight (8.6 g); moderate kernel removal; kernel percentage (38.95%); kernel fill well; kernel veins (20%); kernel colour medium; kernel protein (11.87%) and kernel fat (54.45%).

SS-10

Tree semi-erect; branching medium; yield (19.5 kg/tree); yield efficiency (0.085 kg/cm²). Protandrous; terminal bearer; slight hull persistence after nut fall; leafing time (29th March). Nut ovate in shape through suture and circular in shape perpendicular to suture; shell texture rough; shell colour medium; shell seal strong; shell thickness (1.90 mm); nut weight (10.75 g); easy kernel removal; kernel percentage (43.72%); kernel fill well; kernel veins (20%); kernel colour light; kernel protein (12.02%) and kernel fat (43.80%).

SS-11

Tree spreading; branching dense; yield (10.50 kg/tree); yield efficiency (0.045 kg/cm²). Protandrous; terminal bearer; moderate hull persistence after nut fall; leafing time (28th March). Nut circular in shape through suture and trapezoid in shape perpendicular to suture; shell texture medium; shell colour light; shell seal intermediate; shell thickness (2.08 mm); nut weight (8.50 g); difficult kernel removal; kernel percentage (31.18%); kernel fill well; kernel veins (10%); kernel colour dark; kernel protein (10.65%) and kernel fat (54.45%).

SS-12

Tree semi-erect; branching dense; yield (8.50 kg/tree); yield efficiency (0.054 kg/cm²). Protandrous; terminal bearer; slight hull persistence after nut fall; leafing

time (28th March). Nut ovate in shape through suture and trapezoid in shape perpendicular to suture; shell texture medium; shell colour medium; shell seal strong; shell thickness (1.61 mm); nut weight (7.80 g); moderate kernel removal; kernel percentage (38.46%); kernel fill well; kernel veins (40%); kernel colour dark; kernel protein (12.65%) and kernel fat (41.85%).

SS-13

Tree spreading; branching dense; yield (16.00 kg/tree); yield efficiency (0.039 kg/cm²). Homogamous; terminal bearer; slight hull persistence after nut fall; leafing time (20th March). Nut circular in shape both through suture and perpendicular to suture; shell texture medium; shell colour light; shell seal strong; shell thickness (2.56 mm); nut weight (11.30 g); moderate kernel removal; kernel percentage (42.04%); kernel fill well; kernel veins (10%); kernel colour light; kernel protein (11.21%) and kernel fat (53.45%).

SS-14

Tree semi-erect; branching dense; yield (7.00 kg/tree); yield efficiency (0.022 kg/cm²). Protandrous; terminal bearer; slight hull persistence after nut fall; leafing time (10th April). Nut ovate in shape through suture and trapezoid in shape perpendicular to suture; shell texture rough; shell colour very dark; shell seal strong; shell thickness (1.98 mm); nut weight (8.30 g); moderate kernel removal; kernel percentage (39.76%); kernel fill well; kernel veins (10%); kernel colour light; kernel protein (11.17%) and kernel fat (51.80%).

SS-15

Tree spreading; branching dense; yield (10.00 kg/tree); yield efficiency (0.019 kg/cm²). Protandrous; terminal bearer; slight hull persistence after nut fall; leafing time (8th April). Nut ovate in shape through suture and circular in shape perpendicular to suture; shell texture medium; shell colour medium; shell seal intermediate; shell thickness (2.04 mm); nut weight (7.40 g); moderate kernel removal; kernel percentage

(39.19%); kernel fill moderate; kernel veins (20%); kernel colour dark; kernel protein (12.65%) and kernel fat (46.95%).

SS-16

Tree spreading; branching dense; yield (9.50 kg/tree); yield efficiency (0.015 kg/cm²). Protandrous; terminal bearer; slight hull persistence after nut fall; leafing time (20th March). Nut circular in shape both through suture and perpendicular to suture; shell texture rough; shell colour medium; shell seal intermediate; shell thickness (1.69 mm); nut weight (7.05 g); moderate kernel removal; kernel percentage (43.26%); kernel fill well; kernel veins (20%); kernel colour medium; kernel protein (11.72%) and kernel fat (47.45%).

SS-17

Tree semi-erect; branching medium; yield (15.20 kg/tree); yield efficiency (0.036 kg/cm²). Protandrous; terminal bearer; slight hull persistence after nut fall; leafing time (31st March). Nut ovate in shape both through suture and perpendicular to suture; shell texture medium; shell colour medium; shell seal weak; shell thickness (2.24 mm); nut weight (15.25 g); moderate kernel removal; kernel fill well; kernel veins (20%); kernel colour light; kernel percentage (43.28); kernel protein (12.10%) and kernel fat (48.45%).

SS-18

Tree semi-erect; branching dense; yield (18.00 kg/tree); yield efficiency (0.044 kg/cm²). Homogamous; terminal bearer; moderate hull persistence after nut fall; leafing time (31st March). Nut ovate in shape through suture and trapezoid in shape perpendicular to suture; shell texture rough; shell colour dark; shell seal strong; shell thickness (1.96 mm); nut weight (9.05 g); moderate kernel removal; kernel percentage (37.57%); kernel fill moderate; kernel veins (10%); kernel colour light; kernel protein (11.39%) and kernel fat (48.05%).

SS-19

Tree spreading; branching dense; yield (29.00 kg/tree); yield efficiency (0.044 kg/cm²). Protandrous; terminal bearer; slight hull persistence after nut fall; leafing time (3rd April). Nut circular in shape both through suture and perpendicular to suture; shell texture medium; shell colour light; shell seal intermediate; shell thickness (2.23 mm); nut weight (11.85 g); difficult kernel removal; kernel percentage (43.88%); kernel fill well; kernel veins (40%); kernel colour dark; kernel protein (12.32%) and kernel fat (42.05%).

SS-20

Tree spreading; branching dense; yield (14.50 kg/tree); yield efficiency (0.022 kg/cm²). Protandrous; terminal bearer; slight hull persistence after nut fall; leafing time (5th April). Nut obovate in shape both through suture and perpendicular to suture; shell texture medium; shell colour medium; shell seal weak; shell thickness (2.59 mm); nut weight (10.75 g); difficult kernel removal; kernel percentage (41.86%); kernel fill thin; kernel veins (10%); kernel colour light; kernel protein (11.99%) and kernel fat (54.75%).

SS-21

Tree spreading; branching dense; yield (8.20 kg/tree); yield efficiency (0.015 kg/cm²). Protandrous; terminal bearer; moderate hull persistence after nut fall; leafing time (21st March). Nut elliptic in shape both through suture and perpendicular to suture; shell texture medium; shell colour medium; shell seal strong; shell thickness (2.23 mm); nut weight (8.50 g); medium kernel removal; kernel percentage (36.47%); kernel fill well; kernel veins (10%); kernel colour medium; kernel protein (10.43%) and kernel fat (51.35%).

SS-22

Tree spreading; branching medium; yield (6.50 kg/tree); yield efficiency (0.022 kg/cm²). Protandrous; terminal bearer; slight hull persistence after nut fall;

leafing time (27th March). Nut ovate in shape both through suture and perpendicular to suture; shell texture medium; shell colour light; shell seal strong; shell thickness (2.09 mm); nut weight (7.30 g); difficult kernel removal; kernel percentage (37.67%); kernel fill well; kernel veins (10%); kernel colour light; kernel protein (11.26%) and kernel fat (51.25%).

SS-23

Tree spreading; branching dense; yield (46.00 kg/tree); yield efficiency (0.193 kg/cm²). Protandrous; terminal bearer; slight hull persistence after nut fall; leafing time (2nd April). Nut triangular in shape through suture and trapezoid in shape perpendicular to suture; shell texture rough; shell colour dark; shell seal strong; shell thickness (1.99 mm); nut weight (10.00 g); moderate kernel removal; kernel percentage (38.00%); kernel fill well; kernel veins (20%); kernel colour dark; kernel protein (11.58%) and kernel fat (49.90%).

SS-24

Tree spreading; branching dense; yield (51.50 kg/tree); yield efficiency (0.053 kg/cm²). Near homogamous; terminal bearer; slight hull persistence after nut fall; leafing time (30th March). Nut trapezoid in shape both through suture and perpendicular to suture; shell texture rough; shell colour dark; shell seal intermediate; shell thickness (1.98 mm); nut weight (12.90 g); moderate kernel removal; kernel percentage (39.15%); kernel fill moderate; kernel veins (20%); kernel colour dark; kernel protein (11.32%) and kernel fat (49.35%).

SS-25

Tree spreading; branching dense; yield (18.00 kg/tree); yield efficiency (0.014 kg/cm²). Protandrous; terminal bearer; slight hull persistence after nut fall; leafing time (4th April). Nut circular in shape through suture and trapezoid in shape perpendicular to suture; shell texture very rough; shell colour dark; shell seal strong; shell thickness (2.19 mm); nut weight (12.95 g); difficult kernel removal; kernel

percentage (37.07%); kernel fill well; kernel veins (10%); kernel colour medium; kernel protein (12.20%) and kernel fat (47.45%).

SS-26

Tree spreading; branching dense; yield (53.00 kg/tree); yield efficiency (0.029 kg/cm²). Homogamous; terminal bearer; moderate hull persistence after nut fall; leafing time (25th March). Nut elliptic in shape both through suture and perpendicular to suture; shell texture rough; shell colour medium; shell seal strong; shell thickness (1.97 mm); nut weight (9.60 g); easy kernel removal; kernel percentage (44.27%) and kernel fat (39.75%).

SS-27

Tree spreading; branching dense; yield (42.50 kg/tree); yield efficiency (0.024 kg/cm²). Protandrous; terminal bearer; slight hull persistence after nut fall; leafing time (26th March). Nut circular in shape both through suture and perpendicular to suture; shell texture rough; shell colour medium; shell seal intermediate; shell thickness (2.05 mm); nut weight (9.40 g); moderate kernel removal; kernel percentage (40.43%); kernel fill well; kernel veins (10%); kernel colour light; kernel protein (10.95%) and kernel fat (50.25%).

SS-28

Tree spreading; branching dense; yield (11.50 kg/tree); yield efficiency (0.021 kg/cm²). Protandrous; terminal bearer; slight hull persistence after nut fall; leafing time (4th April). Nut elliptic in shape both through suture and perpendicular to suture; shell texture medium; shell colour dark; shell seal strong; shell thickness (2.13 mm); nut weight (11.00 g); difficult kernel removal; kernel percentage (28.64%); kernel fill moderate; kernel veins (20%); kernel colour medium; kernel protein (11.99%) and kernel fat (49.45%).

SS-29

Tree spreading; branching dense; yield (21.00 kg/tree); yield efficiency (0.043 kg/cm²). Protandrous; terminal bearer; slight hull persistence after nut fall; leafing time (30th March). Nut elliptic in shape both through suture and perpendicular to suture; shell texture smooth; shell colour light; shell seal weak; shell thickness (2.86 mm); nut weight (10.90 g); easy kernel removal; kernel percentage (43.58%); kernel fill well; kernel veins (20%); kernel colour dark; kernel protein (10.84%) and kernel fat (52.95%).

SS-30

Tree semi-erect; branching medium; yield (10.50 kg/tree); yield efficiency (0.055 kg/cm²). Protandrous; terminal bearer; moderate hull persistence after nut fall; leafing time (27th March). Nut trapezoid in shape through suture and ovate in shape perpendicular to suture; shell texture rough; shell colour light; shell seal intermediate; shell thickness (2.59 mm); nut weight (10.55 g); moderate kernel removal; kernel percentage (44.55%); kernel fill well; kernel veins (10%); kernel colour medium; kernel protein (10.61%) and kernel fat (53.30%).

SS-31

Tree semi-erect; branching dense yield (22.00 kg/tree); yield efficiency (0.102 kg/cm²). Protandrous; terminal bearer; slight hull persistence after nut fall; leafing time (1st April). Nut elliptic in shape both through suture and perpendicular to suture; shell texture medium; shell seal strong; shell thickness (1.86 mm); nut weight (9.90 g); easy kernel removal; kernel fill well; kernel veins (10%); kernel colour medium; kernel percentage (45.96%); kernel protein (9.89%) and kernel fat (52.40%).

SS-32

Tree semi-erect; branching medium; yield (14.50 kg/tree); yield efficiency (0.029 kg/cm²). Protandrous; terminal bearer; slight hull persistence after nut fall; leafing time (2nd April). Nut ovate in shape through suture and circular in shape

perpendicular to suture; shell texture rough; shell colour medium; shell seal intermediate; shell thickness (2.57 mm); nut weight (13.75 g); very difficult kernel removal; kernel percentage (40.00%); kernel fill moderate; kernel veins (10%); kernel colour light; kernel protein (10.66%) and kernel fat (53.60%).

SS-33

Tree semi-erect; branching dense; yield (7.00 kg/tree); yield efficiency (0.017 kg/cm²). Protandrous; terminal bearer; slight hull persistence after nut fall; leafing time (3rd April). Nut elliptic in shape through suture and obovate in shape perpendicular to suture; shell texture medium; shell colour light; shell seal intermediate; shell thickness (1.71 mm); nut weight (8.70 g); moderate kernel removal; kernel percentage (42.53%); kernel fill moderate; kernel veins (5%); kernel colour light; kernel protein (10.83%) and kernel fat (64.35%).

SS-34

Tree spreading; branching dense; yield (12.00 kg/tree); yield efficiency (0.022 kg/cm²). Protandrous; terminal bearer; slight hull persistence after nut fall; leafing time (26th March). Nut ovate in shape through suture and trapezoid in shape perpendicular to suture; shell texture rough; shell colour medium; shell seal strong; shell thickness (2.02 mm); nut weight (10.20 g); moderate kernel removal; kernel percentage (37.25%); kernel fill moderate; kernel veins (10%); kernel colour dark; kernel protein (11.80%) and kernel fat (53.20%).

SS-35

Tree spreading; branching medium; yield (8.50 kg/tree); yield efficiency (0.010 kg/cm²). Protandrous; terminal bearer; slight hull persistence after nut fall; leafing time (19th March). Nut triangular in shape through suture and cordate in shape perpendicular to suture; shell texture rough; shell colour medium; shell seal intermediate; shell thickness (1.72 mm); nut weight (13.05 g); easy kernel removal;

kernel percentage (39.08%); kernel fill well; kernel veins (20%); kernel colour medium, kernel protein (12.85%) and kernel fat (60.45%).

SS-36

Tree spreading; branching dense; yield (9.00 kg/tree); yield efficiency (0.014 kg/cm²). Protandrous; terminal bearer; slight hull persistence after nut fall; leafing time (19th March). Nut broad elliptic in shape through suture; nut elliptic in shape perpendicular to suture; shell texture medium; shell seal medium; shell thickness (2.07 mm); nut weight (14.30 g); easy kernel removal; kernel fill moderate; kernel veins (20%); kernel colour medium; kernel percentage (40.56%); kernel protein (13.69%) and kernel fat (47.50%).

SS-37

Tree spreading; branching dense; yield (6.50 kg/tree); yield efficiency (0.013 kg/cm²). Protandrous; terminal bearer; moderate hull persistence after nut fall; leafing time (24th March). Nut ovate in shape through suture and circular in shape perpendicular to suture; shell texture medium; shell colour medium; shell seal strong; shell thickness (2.12 mm); nut weight (10.95 g); easy kernel removal; kernel percentage (40.18%); kernel fill moderate; kernel veins (20%); kernel colour medium; kernel protein (12.19%) and kernel fat (53.45%).

SS-38

Tree spreading; branching dense; yield (5.50 kg/tree); yield efficiency (0.019 kg/cm²). Protandrous; terminal bearer; slight hull persistence after nut fall; leafing time (31st March). Nut ovate in shape through suture and circular in shape perpendicular to suture; shell texture medium; shell colour light; shell seal strong; shell thickness (1.92 mm); nut weight (8.20 g); difficult kernel removal; kernel percentage (47.56%); kernel fill well; kernel veins (40%); kernel colour dark; kernel protein (10.65%) and kernel fat (62.20%).

SS-39

Tree spreading; branching dense; yield (18.00 kg/tree); yield efficiency (0.034 kg/cm²). Protandrous; terminal bearer; moderate hull persistence after nut fall; leafing time (26th March). Nut circular in shape both through suture and perpendicular to suture; shell texture medium; shell colour medium; shell seal strong; shell thickness (2.36 mm); nut weight (12.65 g); moderate kernel removal; kernel percentage (33.60%); kernel fill moderate; kernel veins (20%); kernel colour dark; kernel protein (14.25%) and kernel fat (39.65%).

SS-40

Tree spreading; branching dense; yield (37.00 kg/tree); yield efficiency (0.059 kg/cm²). Protandrous; terminal bearer; moderate hull persistence after nut fall; leafing time (26th March). Nut trapezoid in shape both through suture and perpendicular to suture; shell texture medium; shell colour light; shell seal strong; shell thickness (2.15 mm); nut weight (9.75 g); moderate kernel removal; kernel percentage (45.13%); kernel fill well; kernel veins (20%); kernel colour medium; kernel protein (11.50%) and kernel fat (51.05%).

SS-41

Tree spreading; branching dense; yield (9.50 kg/tree); yield efficiency (0.014 kg/cm²). Protandrous; terminal bearer; moderate hull persistence after nut fall; leafing time (2nd April). Nut trapezoid in shape both through suture and perpendicular to suture; shell texture medium; shell seal strong; shell thickness (1.94 mm); nut weight (12.30 g); moderate kernel removal; kernel fill well; kernel veins (10%). Kernel colour light; kernel percentage (41.87%); kernel protein (12.65%) and kernel fat (45.95%).

SS-42

Tree semi-erect; branching sparse; yield (3.50 kg/tree); yield efficiency (0.012 kg/cm²). Protandrous; terminal bearer; moderate hull persistence after nut fall; leafing

time (3rd April). Nut circular in shape both through suture and perpendicular to suture; shell texture very rough; shell colour dark; shell seal strong; shell thickness (2.25 mm); nut weight (12.40 g); moderate kernel removal; kernel percentage (37.50%); kernel fill well; kernel veins (5%); kernel colour very light; kernel protein (14.25%) and kernel fat (43.30%).

SS-43

Tree semi-erect; branching medium; yield (4.50 kg/tree); yield efficiency (0.023 kg/cm²). Protandrous; terminal bearer; slight hull persistence after nut fall; leafing time (5th April). Nut ovate in shape both through suture and perpendicular to suture; shell texture smooth; shell colour medium; shell seal strong; shell thickness (3.02 mm); nut weight (6.75 g); moderate kernel removal; kernel percentage (40.74%); kernel fill well; kernel veins (20%); kernel colour medium; kernel protein (12.92) and kernel fat (68.70%).

SS-44

Tree semi-erect; branching dense; yield (6.00 kg/tree); yield efficiency (0.016 kg/cm²). Protandrous; terminal bearer; slight hull persistence after nut fall; leafing time (20th March). Nut circular in shape through suture and trapezoid in shape perpendicular to suture; shell texture rough; shell colour medium; shell seal strong; shell thickness (1.92 mm); nut weight (9.30 g); moderate kernel removal; kernel percentage (47.31%); kernel fill well; kernel veins (40%); kernel colour dark; kernel protein (12.32%) and kernel fat (50.25%).

SS-45

Tree semi-erect; branching medium; yield (5.50 kg/tree); yield efficiency (0.026 kg/cm²). Protandrous; terminal bearer; moderate hull persistence after nut fall; leafing time (31st March). Nut circular in shape both through suture and perpendicular to suture; shell texture medium; shell colour medium; shell seal weak; shell thickness (2.36 mm); nut weight (10.05 g); easy kernel removal; kernel percentage (39.80%);

kernel fill well; kernel veins (20%); kernel colour dark; kernel protein (11.13%) and kernel fat (47.00%).

SS-46

Tree spreading; branching medium; yield (4.00 kg/tree); yield efficiency (0.011 kg/cm²). Protandrous; terminal bearer; slight hull persistence after nut fall; leafing time (26th March). Nut broad elliptic in shape through suture; nut circular in shape perpendicular to suture; shell texture rough; shell seal weak; shell thickness (2.07 mm); nut weight (14.45 g); moderate kernel removal; kernel fill well; kernel veins (20%); kernel colour dark; kernel percentage (42.91%); kernel protein (9.94%) and kernel fat (54.60%).

SS-47

Tree spreading; branching medium; yield (2.75 kg/tree); yield efficiency (0.007 kg/cm²). Protandrous; terminal bearer; slight hull persistence after nut fall; leafing time (5th April). Nut triangular in shape through suture and circular in shape perpendicular to suture; shell texture medium; shell colour light; shell seal strong; shell thickness (2.24 mm); nut weight (8.80 g); moderate kernel removal; kernel percentage (40.34%); kernel fill moderate; kernel veins (20%); kernel colour dark; kernel protein (11.80%) and kernel fat (52.66%).

SS-48

Tree semi-erect; branching medium; yield (3.75 kg/tree); yield efficiency (0.021 kg/cm²). Protandrous; terminal bearer; moderate hull persistence after nut fall; leafing time (27th March). Nut circular in shape both through suture and perpendicular to suture; shell texture medium; shell colour light; shell seal intermediate; shell thickness (2.65 mm); nut weight (9.00 g); difficult kernel removal; kernel percentage (30.56%); kernel fill moderate; kernel veins (10%); kernel colour dark; kernel protein (12.09%) and kernel fat (47.15%)

SS-49

Tree semi-erect; branching medium; yield (6.00 kg/tree); yield efficiency (0.018 kg/cm²). Protandrous; terminal bearer; slight hull persistence after nut fall; leafing time (3rd April). Nut broad elliptic in shape through suture and circular in shape perpendicular to suture; shell texture rough; shell colour light; shell seal weak; shell thickness (2.09 mm); nut weight (9.15 g); moderate kernel removal; kernel percentage (53.55%); kernel fill well; kernel veins (20%); kernel colour dark; kernel protein (14.76%) and kernel fat (36.80%).

SS-50

Tree semi-erect; branching dense; yield (8.75 kg/tree); yield efficiency (0.044 kg/cm²). Protandrous; terminal bearer; slight hull persistence after nut fall; leafing time (29th March). Nut ovate in shape both through suture and perpendicular to suture; shell texture rough; shell colour very light; shell seal strong; shell thickness (2.04 mm); nut weight (11.70 g); easy kernel removal; kernel percentage (38.89%); kernel fill well; kernel veins (5%); kernel colour light; kernel protein (10.09%) and kernel fat (58.40%).

SS-51

Tree spreading; branching dense; yield (60.50 kg/tree); yield efficiency (0.008 kg/cm²). Homogamous; moderate hull persistence after nut fall; leafing time (7th April). Nut tapezoid in shape both through suture and perpendicular to suture; shell texture medium; shell seal medium; shell thickness (2.17 mm); nut weight (14.65 g); easy kernel removal; kernel fill well; kernel veins (20%); kernel colour light, kernel percentage (46.42%); kernel protein (12.71%) and kernel fat (66.50%).

SS-52

Tree spreading; branching dense; yield (40.50 kg/tree); yield efficiency (0.013 kg/cm²). Homogamous; terminal bearer; moderate hull persistence after nut fall;

leafing time (21st March). Nut ovate in shape through suture; nut trapezoid in shape perpendicular to suture; shell texture very rough; shell seal strong; shell thickness (2.22 mm); nut weight (13.20 g); moderate kernel removal; kernel fill well; kernel veins (10%); kernel colour light; kernel percentage (45.83%); kernel protein (11.48%) and kernel fat (41.20%).

SS-53

Tree spreading; branching dense; yield (46.75 kg/tree); yield efficiency (0.012 kg/cm²). Homogamous; terminal bearer; slight hull persistence after nut fall; leafing time (29th March). Nut ovate in shape both through suture and perpendicular to suture; shell texture rough; shell seal medium; shell thickness (2.26 mm); nut weight (11.35 g); easy kernel removal; kernel fill well; kernel veins (10%); kernel colour medium, kernel percentage (47.15%); kernel protein (11.25%) and kernel fat (53.25%).

SS-54

Tree spreading; branching medium; yield (49 kg/tree); yield efficiency (0.011 kg/cm²). Homogamous; terminal bearer; moderate hull persistence after nut fall; leafing time (29th March). Nut ovate in shape through suture and perpendicular to suture; shell texture very rough; shell seal medium; shell thickness (2.88 mm); nut weight (13.65 g); easy kernel removal; kernel fill well; kernel veins (10%); kernel colour light; kernel percentage (44.69%); kernel protein (13.58%) and kernel fat (32.70%).

SS-55

Tree spreading; branching medium; yield (50.50 kg/tree); yield efficiency (0.019 kg/cm²). Homogamous; terminal bearer; moderate hull persistence after nut fall; leafing time (29th March). Nut broad elliptic in shape through suture; nut trapezoid in shape perpendicular to suture; shell texture very rough; shell seal strong; shell thickness (2.03 mm); nut weight (14.00 g); easy kernel removal; kernel fill well;

kernel veins (20%); kernel colour medium; kernel percentage (44.64%); kernel protein(12.39%) and kernel fat (50.75%).

SS-56

Tree semi-erect; branching medium; yield (11.75 kg/tree); yield efficiency (0.012 kg/cm²). Protandrous; terminal bearer; slight hull persistence after nut fall; leafing time (13th April). Nut ovate in shape through suture and trapezoid in shape perpendicular to suture; shell texture very rough; shell colour medium; shell seal strong; shell thickness (1.96 mm); nut weight (11.15 g); very difficult kernel removal; kernel percentage (35.53%); kernel fill moderate; kernel veins (10%); kernel colour light; kernel protein (17.36%) and kernel fat (39.55%).

SS-57

Tree spreading; branching dense; yield (20.50 kg/tree); yield efficiency (0.010 kg/cm²). Protandrous; terminal bearer; slight hull persistence after nut fall; leafing time (12th April). Nut elliptic in shape through suture and obovate in shape perpendicular to suture; shell texture very rough; shell colour medium; shell seal strong; shell thickness (2.98 mm); nut weight (16.10 g); moderate kernel removal; kernel percentage (38.51%); kernel fill well; kernel veins (10%); kernel colour medium; kernel protein (10.54%) and kernel fat (54.65%).

4.5 CORRELATION STUDIES

The results (Table 9) obtained with respect to correlation analysis between various tree, foliage, floral, nut and kernel characteristics are presented as under:

Leafing time was observed to be positively and significantly correlated with first male bloom date ($r=0.606$), peak male bloom date ($r=0.614$), last male bloom date ($r=0.602$), first female bloom date ($r=0.426$), peak female bloom date ($r=0.465$), last female bloom date ($r=0.555$), trunk cross sectional area ($r=0.263$), nut diameter

perpendicular to suture ($r=0.267$) and kernel percentage ($r=0.357$). Negative and significant association of leafing time was observed with leaf fall ($r=-0.406$).

Duration of female bloom ($r=0.400$) and fat percentage ($r=0.358$) were positively and significantly associated with time of leaf fall. Whereas, first male bloom date ($r=-0.374$), peak male bloom date ($r=-0.311$), first female bloom date ($r=-0.418$), peak female bloom date ($r=-0.341$) and last female bloom date ($r=-0.281$) showed negative and significant association with leaf fall. Positive and significant relationship of harvesting time was observed with duration of male bloom ($r=0.328$) and fat percentage ($r=0.321$), but negative and significant relationship with duration of female bloom ($r=-0.46$) and kernel percentage ($r=-0.291$).

Duration of male bloom was significantly and positively correlated with trunk girth ($r=0.526$), trunk cross sectional area ($r=0.406$), yield ($r=0.442$), nut diameter through suture ($r=0.363$), kernel weight ($r=0.259$) and number of nuts/tree ($r=0.256$). Negative and significant association of duration of male bloom was observed with dichogamy ($r=-0.587$), first male bloom date ($r=-0.261$), first female bloom date ($r=-0.289$) and peak female bloom date ($r=-0.295$).

Yield ($r=0.296$), kernel percentage ($r=0.291$), kernel weight ($r=0.272$) and number of nuts/tree ($r=0.264$) were positively and significantly associated with duration of female bloom but negatively and significantly associated with first female bloom date ($r=-0.434$).

Degree of dichogamy was positively and significantly correlated with first female bloom date ($r=0.427$), peak female bloom date ($r=0.387$), last female bloom date ($r=0.284$) and protein percentage ($r=0.285$) whereas, negatively and significantly correlated with peak male bloom rate ($r=-0.313$), last male bloom date ($r=-0.299$), trunk girth ($r=-0.424$) and yield ($r=-0.441$).

Positive and significant relationship of first male bloom date was observed with peak male bloom date ($r=0.934$), last male bloom date ($r=0.858$), first female

bloom date ($r=0.691$), peak female bloom date ($r=0.721$), last female bloom date ($r=0.771$), yield efficiency ($r=0.272$) and kernel percentage ($r=0.270$).

Peak male bloom date found to be positively and significantly associated with last male bloom date ($r=0.931$), first female bloom date ($r=0.597$), peak female bloom date ($r=0.639$), last female bloom date ($r=0.719$), trunk cross sectional area ($r=0.312$), yield ($r=0.333$) and kernel percentage ($r=0.321$).

Whereas last male bloom date was positively and significantly correlated with first female bloom date ($r=0.536$), peak female bloom date ($r=0.573$), last female bloom date ($r=0.699$), trunk cross sectional area ($r=0.339$) and kernel percentage ($r=0.380$).

Positive and significant relationship of first female bloom date was observed with peak female bloom date ($r=0.952$), last female bloom date ($r=0.799$) and kernel percentage ($r=0.280$) whereas, it was negatively and significantly correlated with number of nuts per tree ($r=-0.253$). Positive and significant correlation of peak female bloom date was observed with last female bloom date ($r=0.883$) and kernel percentage ($r=0.417$) whereas fat percentage ($r=-0.272$) was negatively and significantly correlated with peak female bloom date. Last female bloom date was positively and significantly correlated with nut diameter through suture ($r=0.319$), kernel percentage ($r=0.416$) and kernel weight ($r=0.289$) and significantly but negatively correlated with fat percentage ($r=-0.297$).

Shell thickness was positively and significantly correlated with protein percentage ($r=0.321$). Trunk girth was positively and significantly correlated with trunk cross sectional area ($r=0.775$), yield ($r=0.872$), nut diameter through suture ($r=0.533$), diameter perpendicular to suture ($r=0.488$), in-shell nut weight ($r=0.451$), kernel weight ($r=0.455$) and protein percentage ($r=0.317$).

Yield ($r=0.770$), nut diameter through suture ($r=0.425$), nut diameter perpendicular to suture ($r=0.413$), in-shell nut weight ($r=0.428$) and kernel weight

Table 9. Correlation coefficient among various tree, foliage, floral, nut and kernel characters in walnut trees of seedling origin

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	1.000																									
2	-0.406*	1.000																								
3	-0.007	0.176	1.000																							
4	0.055	0.202	0.328*	1.000																						
5	0.080	0.400*	-0.460*	0.098	1.000																					
6	-0.155	-0.177	-0.144	-0.587*	-0.247	1.000																				
7	0.606*	-0.374*	0.008	-0.261*	-0.155	-0.081	1.000																			
8	0.614*	-0.311*	0.078	0.051	-0.111	-0.313*	0.934*	1.000																		
9	0.602*	-0.183	0.174	0.132	-0.105	-0.299*	0.858*	0.931*	1.000																	
10	0.426*	-0.418*	0.070	-0.289*	-0.434*	0.427*	0.691*	0.597*	0.536*	1.000																
11	0.465*	-0.341*	-0.137	-0.295*	-0.170	0.387*	0.721*	0.639*	0.573*	0.952*	1.000															
12	0.555*	-0.281*	-0.078	-0.160	0.001	0.284*	0.771*	0.719*	0.699*	0.799*	0.883*	1.000														
13	0.037	0.133	0.000	0.065	0.114	-0.013	0.007	0.021	0.001	0.056	0.077	0.162	1.000													
14	0.156	0.101	-0.040	0.526*	0.216	-0.424*	0.035	0.237*	0.229	-0.160	-0.091	0.044	-0.024	1.000												
15	0.263*	0.152	0.038	0.406*	0.095	-0.160	0.147	0.312*	0.339*	0.149	0.203	0.228	0.035	0.775*	1.000											
16	0.138	0.222	0.012	0.442*	0.296*	-0.441*	0.168	0.333*	0.246	-0.047	0.039	0.124	0.022	0.872*	0.770*	1.000										
17	0.110	-0.144	0.058	-0.085	0.028	-0.137	0.272*	0.241	-0.006	0.188	0.175	0.119	-0.117	0.058	0.038	0.372*	1.000									
18	0.157	-0.060	-0.017	0.363*	0.076	-0.045	-0.001	0.127	0.077	-0.048	-0.015	0.208	-0.129	0.533*	0.425*	0.475*	0.196	1.000								
19	0.267*	-0.071	-0.073	0.104	0.143	-0.023	0.152	0.222	0.239	0.099	0.155	0.319*	-0.086	0.488*	0.413*	0.405*	0.028	0.759*	1.000							
20	0.227	-0.186	-0.324	0.182	0.217	-0.013	0.030	0.105	-0.035	0.101	0.181	0.196	0.196	0.143	0.089	0.112	0.227	0.416*	0.315*	1.000						
21	-0.077	0.053	0.034	0.199	0.164	0.013	-0.040	0.023	0.078	-0.085	-0.052	0.125	-0.016	0.451*	0.428*	0.386*	-0.054	0.602*	0.742*	0.359*	1.000					
22	0.357*	0.088	-0.291*	0.213	0.291*	-0.081	0.270*	0.321*	0.380*	0.280*	0.417*	0.416*	0.083	0.145	0.238	0.174	-0.011	0.268*	0.324*	0.550*	0.187	1.000				
23	0.104	0.094	-0.108	0.259*	0.272*	-0.042	0.101	0.178	0.249	0.066	0.157	0.289*	0.030	0.455*	0.483*	0.416*	-0.046	0.582*	0.725*	0.540*	0.892*	0.605*	1.000			
24	0.216	-0.085	-0.236	0.064	0.188	0.285*	-0.167	-0.206	-0.124	0.024	0.081	0.165	0.321*	0.317*	0.201	0.129	-0.226	0.252*	0.305*	0.231	0.177	0.377*	0.304*	1.000		
25	-0.240	0.358*	0.321*	0.017	-0.021	-0.142	-0.116	-0.136	-0.150	-0.213	-0.272*	-0.297*	-0.008	-0.121	0.043	0.140	0.228	0.006	-0.094	-0.144	0.112	0.039	0.105	-0.164	1.000	
26	0.175	0.194	0.057	0.256*	0.264*	-0.216	-0.048	0.075	0.234	-0.253*	-0.161	-0.011	0.008	0.088	0.186	0.009	-0.342	0.080	0.044	-0.046	0.083	0.072	0.106	-0.126	-0.225	1.000

*Significant at 5% level of significance

- | | | | | | |
|----------------------------|------------------------------|------------------------------|---|-------------------------|------------------------------|
| 1 - Leafing time | 5 - Duration of female bloom | 10 - First female bloom date | 15 - Trunk cross sectional area | 20 - Nut length | 25 - Kernel fat |
| 2 - Time of leaf fall | 6 - Degree of Dichogamy | 11 - Peak female bloom date | 16 - Yield | 21 - Inshell nut weight | 26 - Number of nuts per tree |
| 3 - Harvesting time | 7 - First male bloom date | 12 - Last female bloom date | 17 - Yield efficiency | 22 - Kernel percentage | |
| 4 - Duration of male bloom | 8 - Peak male bloom date | 13 - Shell thickness | 18 - Nut diameter through suture | 23 - Kernel weight | |
| | 9 - Last male bloom date | 14 - Trunk girth | 19 - Nut diameter perpendicular to suture | 24 - Kernel protein | |

Table 10. Direct and indirect effects of various tree, foliage, floral, nut and kernel characters on nut yield.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Correlation coefficient
1	-1.131	0.054	0.001	0.100	0.055	-0.020	2.716	-2.268	0.261	0.156	0.149	-0.345	-0.004	0.042	0.102	-0.005	-0.025	0.435	0.186	0.419	-1.212	0.518	0.053	-0.162	0.064	0.138
2	0.459	-0.134	-0.027	0.369	0.275	-0.023	-1.675	1.151	-0.079	-0.153	-0.109	0.175	-0.013	0.028	0.059	0.007	0.010	-0.116	-0.153	-0.288	-0.297	0.467	-0.021	0.241	0.071	0.222
3	0.008	-0.024	-0.155	0.601	-0.316	-0.019	0.034	-0.286	0.076	0.026	-0.044	0.049	0.000	-0.011	0.015	-0.003	0.003	-0.119	-0.266	-0.187	0.988	-0.536	-0.057	0.217	0.021	0.012
4	-0.062	-0.027	-0.051	1.831	0.068	-0.077	-1.167	-0.189	0.057	-0.106	-0.095	0.099	-0.006	0.143	0.158	0.004	-0.059	0.170	0.149	-1.085	-0.724	1.288	0.016	0.012	0.094	0.442*
5	-0.091	-0.054	0.072	0.180	0.687	-0.032	-0.692	0.408	-0.046	-0.160	-0.055	0.000	-0.011	0.059	0.037	-0.001	-0.012	0.233	0.178	-0.896	-0.989	1.353	0.046	-0.014	0.096	0.296*
6	0.175	0.024	0.022	-1.074	-0.170	0.131	-0.364	1.155	-0.129	0.157	0.124	-0.177	0.001	-0.115	-0.062	0.007	0.007	-0.038	-0.011	-0.069	0.276	-0.207	0.070	-0.096	-0.079	-0.441*
7	-0.686	0.050	-0.001	-0.477	-0.106	-0.011	4.479	-3.450	0.371	0.254	0.231	-0.480	-0.001	0.010	0.057	-0.013	0.000	0.248	0.025	0.218	-0.917	0.503	-0.041	-0.078	-0.018	0.168
8	-0.695	0.042	-0.012	0.093	-0.076	-0.041	4.182	-3.695	0.403	0.219	0.205	-0.447	-0.002	0.064	0.121	-0.012	-0.021	0.362	0.086	-0.126	-1.091	0.887	-0.050	-0.092	0.027	0.333*
9	-0.681	0.025	-0.027	0.243	-0.072	-0.039	3.842	-3.439	0.433	0.197	0.183	-0.435	0.000	0.062	0.131	0.000	-0.012	0.390	-0.028	-0.426	-1.291	1.238	-0.030	-0.101	0.085	0.247
10	-0.482	0.056	-0.011	-0.529	-0.298	0.056	3.097	-2.205	0.232	0.367	0.305	-0.497	-0.005	-0.043	0.058	-0.009	0.008	0.162	0.083	0.465	-0.952	0.328	0.006	-0.144	-0.093	-0.047
11	-0.526	0.046	0.021	-0.541	-0.117	0.051	3.230	-2.361	0.248	0.350	0.320	-0.549	-0.007	-0.025	0.079	-0.009	0.003	0.253	0.149	0.282	-1.416	0.783	0.020	-0.184	-0.059	0.039
12	-0.627	0.038	0.012	-0.293	0.000	0.037	3.453	-2.655	0.303	0.294	0.282	-0.622	-0.016	0.012	0.089	-0.006	-0.034	0.519	0.161	-0.683	-1.413	1.438	0.040	-0.201	-0.004	0.124
13	-0.042	-0.018	0.001	0.119	0.079	-0.002	0.030	-0.076	0.001	0.020	0.025	-0.101	-0.096	-0.007	0.014	0.006	0.021	-0.140	0.161	0.087	-0.283	0.149	0.078	-0.005	0.003	0.022
14	-0.176	-0.014	0.006	0.964	0.148	-0.055	0.157	-0.877	0.099	-0.059	-0.029	-0.028	0.002	0.272	0.300	-0.003	-0.086	0.795	0.118	-2.465	-0.492	2.266	0.077	-0.081	0.032	0.872*
15	-0.297	-0.020	-0.006	0.744	0.066	-0.021	0.656	-1.151	0.147	0.055	0.065	-0.142	-0.003	0.210	0.388	-0.002	-0.069	0.673	0.073	-2.337	-0.807	2.404	0.049	0.029	0.068	0.770*
16	-0.125	0.019	-0.009	-0.156	0.020	-0.018	1.217	-0.892	-0.003	0.069	0.056	-0.074	0.011	0.016	0.015	-0.049	-0.032	0.045	0.186	0.292	0.037	-0.228	-0.055	0.154	-0.125	0.372*
17	-0.177	0.008	0.003	0.665	0.052	-0.006	-0.003	-0.469	0.033	-0.018	-0.005	-0.130	0.012	0.145	0.165	-0.010	-0.162	1.237	0.342	-3.289	-0.911	2.897	0.062	0.004	0.029	0.475*
18	-0.302	0.010	0.011	0.191	0.098	-0.003	0.682	-0.821	0.104	0.036	0.050	-0.198	0.008	0.132	0.160	-0.001	-0.123	1.630	0.259	-4.051	-1.102	3.609	0.074	-0.064	0.016	0.405*
19	-0.257	0.025	0.050	0.333	0.149	-0.002	0.135	-0.388	-0.015	0.037	0.058	-0.122	-0.019	0.039	0.034	-0.011	-0.067	0.513	0.822	-1.963	-1.869	2.686	0.056	-0.097	-0.017	0.112
20	0.087	-0.007	-0.005	0.363	0.113	0.002	-0.179	-0.085	0.034	-0.031	-0.017	-0.078	0.002	0.123	0.166	0.003	-0.097	1.208	0.295	-5.463	-0.634	4.439	0.043	0.076	0.030	0.386*
21	-0.404	-0.012	0.045	0.390	0.200	-0.011	1.209	-1.187	0.165	0.103	0.133	-0.259	-0.008	0.039	0.092	0.001	-0.043	0.529	0.452	-1.020	-3.397	3.011	0.092	0.027	0.027	0.175
22	-0.118	-0.013	0.017	0.474	0.187	-0.005	0.453	-0.658	0.108	0.024	0.050	-0.180	-0.003	0.124	0.187	0.002	-0.094	1.181	0.443	-4.871	-2.055	4.979	0.074	0.071	0.039	0.416*
23	-0.245	0.011	0.037	0.117	0.129	0.037	-0.746	0.763	-0.054	0.009	0.026	-0.102	-0.031	0.086	0.078	0.011	-0.041	0.496	0.190	-0.967	-1.279	1.515	0.244	-0.111	-0.046	0.129
24	0.272	-0.048	-0.050	0.032	-0.014	-0.019	-0.519	0.503	-0.065	-0.078	-0.087	0.185	0.001	-0.033	0.017	-0.011	-0.001	-0.154	-0.119	-0.614	-0.134	0.523	-0.040	0.675	-0.082	0.140
25	-0.198	-0.026	-0.009	0.469	0.181	-0.028	-0.216	-0.276	0.101	-0.093	-0.052	0.007	-0.001	0.024	0.072	0.017	-0.013	0.072	-0.038	-0.451	-0.246	0.529	-0.031	-0.152	0.366	0.009

Residual effect = 0.00

Bold figures represent direct effects * Significant at 5% level of significance

- 1 - Leafing time
- 2 - Time of leaf fall
- 3 - Harvesting time
- 4 - Duration of male bloom
- 5 - Duration of female bloom

- 6 - Degree of Dichogamy
- 7 - First male bloom date
- 8 - Peak male bloom date
- 9 - Last male bloom date
- 10 - First female bloom date

- 11 - Peak female bloom date
- 12 - Last female bloom date
- 13 - Shell thickness
- 14 - Trunk girth
- 15 - Trunk cross sectional area

- 16 - Yield efficiency
- 17 - Nut diameter through suture
- 18 - Nut diameter perpendicular to suture
- 19 - Nut length
- 20 - Inshell nut weight

- 21 - Kernel percentage
- 22 - Kernel weight
- 23 - Kernel protein
- 24 - Kernel fat
- 25 - Number of nuts per tree

($r=0.483$) were positively and significantly correlated with trunk cross-sectional area (Table 9).

Positive and significant relationship of yield was seen with yield efficiency ($r=0.372$), nut diameter through suture ($r=0.475$), nut diameter perpendicular to suture ($r=0.405$), in-shell nut weight ($r=0.386$) and kernel weight ($r=0.416$).

Nut diameter through suture was significantly and positively associated with nut diameter perpendicular to suture ($r=0.759$), nut length ($r=0.416$), in-shell nut weight ($r=0.602$), kernel percentage ($r=0.268$), kernel weight ($r=0.582$) and protein percentage ($r=0.252$).

Nut diameter perpendicular to suture was positively and significantly correlated with nut length ($r=0.315$), in shell nut weight ($r=0.742$), kernel percentage ($r=0.324$), kernel weight ($r=0.725$), and kernel protein ($r=0.305$).

Nut length was positively and significantly associated with in shell nut weight ($r=0.359$), kernel percentage ($r=0.550$) and kernel weight ($r=0.540$).

In-shell nut weight was found to be significantly and positively correlated with kernel weight ($r=0.892$). Kernel percentage showed positive and significant relationship with kernel weight ($r=0.605$) and protein percentage ($r=0.377$). Whereas kernel weight was found to be positively and significantly correlated with protein percentage ($r=0.304$).

4.6 PATH ANALYSIS

In path analysis 25 different tree, foliage, floral, nut and kernel characters were considered as independent variables and nut yield/tree was taken as dependent variable. The direct and indirect effects of various characters were worked out at phenotypic level and are presented in Table 10.

Direct positive effect on nut yield was observed with duration of male bloom (1.831), duration of female bloom (0.6873), trunk girth (0.272), trunk cross-sectional area (0.388), nut diameter perpendicular to suture and kernel weight (4.979).

Peak male bloom date showed indirect positive effect on yield via leaf fall (0.042), duration of male bloom date (0.093), trunk girth (0.0644), trunk cross-sectional area (0.121) and kernel weight (0.887). Yield efficiency was positively but indirectly associated with yield via first male bloom date (1.217), trunk girth (0.016), trunk cross sectional area (0.015), in-shell nut weight (0.292) and kernel percentage (0.037).

Nut diameter through suture showed indirect positive effect on yield via kernel weight (2.897), nut diameter perpendicular to suture (1.237), trunk girth (0.145), trunk cross sectional area (0.165), duration of male bloom (0.665) and duration of female bloom (0.052).

In-shell nut weight showed indirect positive effect (Table 10) on yield via kernel weight (4.439), nut diameter perpendicular to suture (1.208), trunk girth (0.123), trunk cross sectional area (0.166), duration of male bloom date (0.363) and duration of female bloom (0.113). Dichogamy showed negative indirect effect on yield via first male bloom date (-0.364), peak male bloom date (-0.129), peak female bloom date (-0.177) and nut length (-0.011).

Chapter-5
DISCUSSION

DISCUSSION

Persian walnut trees are grown from seed since times immemorial and are so grown even today in many parts of the world including India. With the standardization of budding or grafting techniques for successful propagation of walnuts people started selecting scion wood from the trees of seedling origin in a particular area with an aim to develop superior cultivars. Thus superior individual seedlings chosen as scionwood sources became the cultivars used by growers. The typical example is of French cultivar 'Franquette'. During the last 4-5 decades there have been surveys of thousands of seedling trees in many countries including France, Spain, Yugoslavia, Poland, Czech Republic, Bulgaria, Guinea, Moldavia and China. In India too, the seeds of superior strains are used for raising planting material which gives variable stand and the age of bearing trees extend upto hundred or more years. There are no standard walnut cultivars in cultivation in the country. Like in other countries, as mentioned above, field surveys have been undertaken in walnut growing regions in India to select superior individual seedling trees (Sharma and Kumar, 1994) and the process is continuing with several potential areas yet to be explored. Many of such surveys in the past have been confined to quantification of the variation for most of the metric traits but the situation improved later with the development of vegetative propagation methods in walnut. Keeping in line with the above, a study was proposed to survey a part of district Sirmour (not explored earlier) to select walnut trees with superior traits. The results so obtained with respect to selection of superior walnuts from seedling tree populations in Deedag, Chauras, Chikhria, Khal and Gandoori villages of district Sirmour are discussed as under:

5.1 FIELD SURVEYS

Survey work in five villages undertaken in year 2001 revealed that out of a total of 342 trees screened only 57 trees were found to be regular in bearing and had good nut and kernel characteristics. The existence of large number of trees either irregular in bearing or not in bearing and those having extremely small and hard shelled nuts, points towards the fact that walnut growing in the region is primitive and neglected by and large. Only in a very few pockets, the walnut trees of seedling origin were being taken care of though to a little extent, for example in Chikhria (Ser Tundla). However, this does reflect that the walnut germplasm in these villages constitute genetically diverse types owing to their unknown origin, propagation through seed coupled with varied microenvironment. Thus a systematic characterization and evaluation of the selected 57 trees was all the more important to select the superior genotypes from commercialization and conservation point of view in future.

5.2 CHARACTERIZATION AND EVALUATION

5.2.1 Tree Characters

An ideal walnut tree is that which grows vigorously to moderate and yielding considerably (Forde, 1975). Important tree attributes such as growth habit (erect to spreading), trunk girth (26.0-308.0 cm), trunk cross-sectional area (53.82-5476.80 cm²), number of nuts/tree (234-5505 nuts/tree), yield (2.75-60.5 kg/tree) and yield efficiency (0.007-0.266 kg/cm²) varied considerably among the 57 trees studied here (Table 1 and 2).

Large differences in these characters are similar to previous findings on walnut trees of seedling origin (Nauriyal *et al.*, 1970; Sharma and Chauhan, 1980; Sharma and Sharma, 1997a, 2000a) which can be attributed to their seedling origin and age differences. However, yield efficiency which largely covers up the variation due to age also varied a lot between the 57 trees. SS-2 had the highest yield efficiency (0.266 kg/cm²) which is far greater than the yield efficiency reported by other workers from

different parts of Himachal Pradesh i.e. upto 0.0236 kg/cm² (Sharma and Sharma (2000b) from Garsa valley (Kullu), Jogindernagar (Mandi), Bharmour (Chamba) and Nauradhar (Sirmour). Even the high yielding (upto 105 kg/tree) selections from district Shimla had a maximum of 0.100 kg/cm² yield efficiency as reported by Attar (2001). This reflects higher yield potential of some of the selections studied here. Similar trends of extreme variation in number of nuts/tree observed here further supports the fact that these trees constitute a diverse gene pool. Variation was also reported earlier in number of nuts in walnut trees of seedling origin in Jaunsar Bhabhar area of Garhwal hills in Uttaranchal (Pandey and Sinha, 1984) and in naturally occurring wild persian walnut trees in Iran (Atefi, 1990). In the present study, time of harvesting of nuts as indicated by hull splitting was observed to vary over a period of one month in different selections with earliest (31st July) in SS-53 to as late as 1st September in SS-57 (Table 1). Unlike previous reports from other parts of Himachal Pradesh and Uttaranchal (Lal and Singh, 1978), the time of nut maturity (Sharma and Sharma, 1998a, 2000a) observed here is little early as reported earlier by Sharma and Sharma (2000b) in Tree No.11 from Nauradhar (Sirmour), which may be due to relatively warmer climate in the area of study. Shoot colour, an important descriptor for characterization of walnuts varied between green brown, blackish and pale brown in all the trees studied here (Table 2) which is similar to findings of Sharma and Sharma (1997a, 1998a). The occurrence of blackish shoot colour is in contrast to the findings of Singh (1993) who recorded only pale brown and green brown shoots in walnut trees of seedling origin in Parvati valley of Kullu. However, walnut cultivars like 'Corne' and 'Marbot' exhibit blackish coloured one year old shoots (UPOV, 1988), whereas selections from district Shimla had only brown colour (Attar, 2001) shoots.

5.2.2 Foliage Characters

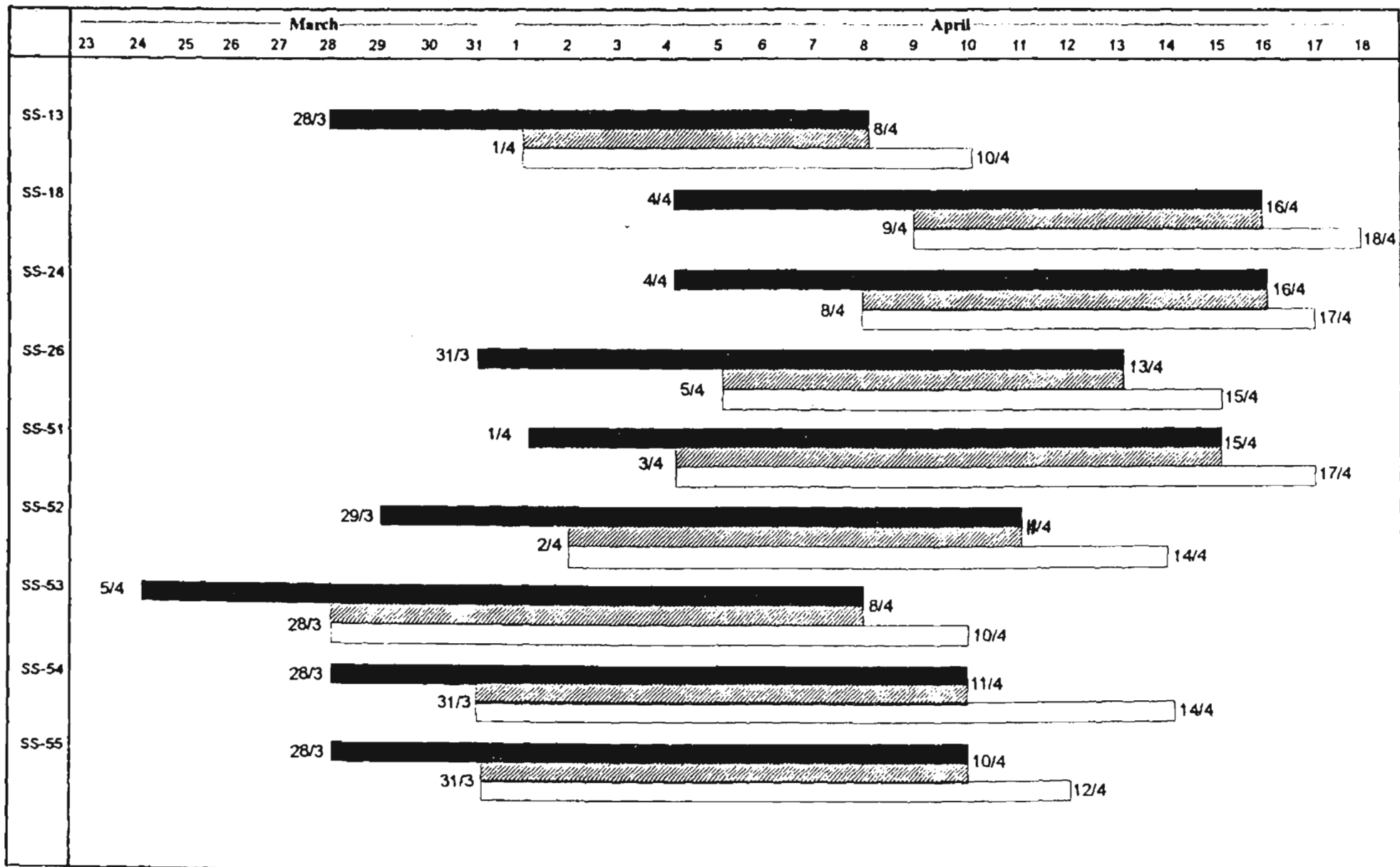
Leafing time is another important walnut character particularly late leafing avoiding thereby damage due to spring frosts. In the present study, the date of leaf bud burst ranged from 19th March to 13th April in various selections (Table 3). In a study

on seedling walnut trees in Nauradhar area of district Sirmour, Sharma (1999) also recorded leaf bud burst time between 10th March and 15th April. Other studies conducted elsewhere also indicate large variation in leaf bud burst time (Hlisc, 1973; Mitrovic, 1988; Atefi, 1993; Singh, 1993; Aleta and Ninot, 1997; Ribeiro da Silva *et al*, 1997)

Various other foliage characters viz. leaf length and width, number and width of leaflets, rachis colour, pubescence and persistence of leaf and rachis also varied considerably (Table 3 and 4) similar to other reports from Himachal Pradesh (Singh, 1993; Sharma, 1996, 1999; Attar, 2001). Time of leaf fall is another important trait in walnut from climatic adaptation point of view with late leaf fall being preferred. The variation in time of leaf fall as recorded in seedling trees studied here is in conformity to earlier reports from Himachal Pradesh (Sharma and Sharma, 2000a).

5.2.3 Floral and Fruiting Characters

Persian walnut genotypes range from almost lateral bearing to those in which only the terminal bud produces the flowers (McGranahan and Leslie, 1990). The latter condition has been observed in all the 57 trees studied here i.e. only terminal bearing habit was recorded (Appendix-II), though light to heavy female flower abundance was observed in different selections (Table 6 and Appendix-II). Nature and extent of dichogamy in walnut varies from almost complete overlap (homogamy) to complete separation of male and female bloom period with either the male blooming first (protandry) or the female i.e. protogyny (Meza, 1975; McGranahan and Leslie, 1990). However, 57 tree selections studied here were found to be largely protandrous (Table 6) and some nine as almost homogamous (Fig.9) with none as protogynous. Although degree of dichogamy varies somewhat year to year, yet the overlap of pistillate and staminate bloom observed here is a desirable breeding objective as contended by Forde and McGranahan (1996). Hull dehiscence and its persistence after nut fall are varietal characters (UPOV, 1988). Both these characters varied moderately in 57 tree selections studied here (Table 6 and Appendix-II) which is in accordance with the





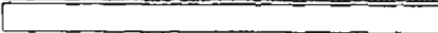
 - Male bloom period
 - Time of female bloom overlapped by male bloom
 - Female bloom period

Fig. 9: Homogamy in some walnut tree selections

findings of Attar (2001) in walnut tree selections from district Shimla of Himachal Pradesh.

5.2.4 Nut and Kernel Characters

An ideal nut would weigh between 12-18 g having clean, strong and tightly sealed thin shell with easily removable light coloured, clean and plump kernel weighing at least 50 per cent of nut (McGranahan and Leslie, 1990). Since most of the nut and kernel characters are moderately to highly heritable (Hansche *et al.*, 1972), the selection on the basis of these characters would be an effective method of genetic improvement (Forde, 1975). In the present study, an effort has also been made to evaluate seedling trees on the basis of their nut and kernel traits, and to locate the ones with superior performance, for multiplication and distribution after further testing.

5.2.4.1 Nut Characters: Nut size (length, diameter, weight), shape, colour, shell strength and sealing of shell halves have often been considered important marketing attributes and for almost every such trait, there exists a great deal of variation. In the present study, nut weight varied considerably from 6.75 g (SS-43) to 16.1 g (SS-57) amongst the seedling trees (Table 7) but fell well within the high ranges of 17-26 g reported in India (Pandey and Sinha, 1984), Yugoslavia (Kuzmannovski *et al.*, 1976), Bulgaria (Popov, 1983), Turkey (Sykes, 1975), Maldivia (Tsurkan *et al.*, 1974; Komanich, 1974) and Greece (Rouskas *et al.*, 1997) and low range of less than 6 g reported from hills of Uttar Pradesh (Lal and Singh, 1978). Nut length and diameter also varied considerably in different selections studied here similar to earlier reports from Yugoslavia (Paunovic, 1990) and India as well (Nauriyal *et al.*, 1970; Chauhan and Sharma, 1980; Pandey and Sinha, 1984; Sharma and Sharma, 1997a, 1998b, 2000b, 2001; Gautam, 2000; Attar, 2001). On the whole, in persian walnut, nut size can range from less than 2 cm to over 6 cm with almost equal diameter but does not necessarily reflect kernel size (McGranahan and Leslie, 1990).

In the present study, nut shape varied considerably in different selections (Table 8a and Appendix-III). Nuts of various cultivars of commercial significance

falls into such categories on the basis of nut shape, as indicated in UPOV (1988) guidelines on walnut.

The nut colour of different seedling trees varied from very light brown (SS-31 and SS-50) to very dark brown (SS-14 and SS-53) with remaining selections having light brown, medium and dark brown shell coloured nuts (Table 8b and Appendix-III). Though light coloured shells are preferred from marketing point of view of in-shell nuts, yet moderate to dark brown shell colour is reported in walnut.

Important shell characters include shell thickness, weight of shell, width of pad on suture and shell seal. Shell texture is another trait of significance, particularly, reasonably smooth, thin and completely sealed shells are desirable (McGranahan and Leslie, 1990). In the present study, shell texture varied from smooth, intermediate, rough to very rough in the selected trees (Table 8b). Among the selected 57 walnut seedling trees, SS-2, SS-29 and SS-43 had smooth shell texture (Appendix-III). Shells of persian walnuts vary from extremely thick and durable (resembling those of black walnuts) to paper thin shells which can be easily crushed in hand. In the present study, shell thickness in nuts of seedling trees varied considerably with as many as 21 trees having nut shell thickness in the range of 1.5 mm to 2.0 mm, a desired strength for long distance transportation, especially for export purposes. The reported shell thickness ranged from a low of 0.2 mm (Rathore, 1984) to a high of 4.3 mm (Chauhan and Sharma, 1979). There may be more thick shelled strains in nature as indicated by Sharma and Kumar (1994). In California, for local marketing, minimum shell thickness acceptable is 1.4-1.5 mm with little higher values for walnuts harvested mechanically and for distant marketing (McGranahan and Leslie, 1990). Nut seal if weak, would allow entry of insects or dirt and break apart easily, thereby creating the altogether different problems than caused by excessively thin shells. In the present investigation, seedling trees exhibited weak, medium and strong sealing. Among the promising types, shells of nuts of six selections namely SS-2, SS-3, SS-31, SS-41, SS-52 and SS-55 were strongly sealed (Appendix-III).

5.2.4.2 Kernel Characters: Kernel characters are extremely important marketing attributes in view of the fact that in the international market increasing quantities of produce is sold as kernel rather than in-shell nut. This nevertheless, does not undermine the importance of nut characters as discussed earlier. Both nut and kernel quality are strongly affected by genotype, environment and their interaction (McGranahan and Leslie, 1990).

Kernel characters like colour, weight, percentage etc. have been reported to vary considerably in samples from trees of seedling populations. Seedling trees included in the present study showed significant variation in kernel weight and in kernel percentage (Table 7). The kernel colour varied from very light, light, medium to dark (Table 8c and Appendix-III). Among the promising 12 seedling tree selections, SS-17, SS-51, SS-53 and SS-54 had light kernel colour (Appendix-III). In previous reports, range of kernel weight extended from as high as 21.0 g to as low as 1.2 g (Nauriyal *et al.*, 1970; Sykes, 1975; Cheng, 1978; Sharma and Chauhan, 1980; Pandey and Sinha, 1984; Rathore, 1984; Singh, 1993; Kaska *et al.*, 1993; Sharma and Sharma, 1997a, 1998b, 2000b; Attar, 2001; Kazankaya *et al.*, 2001). Earlier, Forde (1975) indicated that desirable kernel weight should be 10-11 g. Although there are reports of much higher values of kernel percentage upto 80 per cent (Motial and Gilkar, 1970; Barton, 1979; Komanich, 1974) the maximum kernel percentage obtained in the present study was 53.55 per cent. Similar variation for this character was obtained by various workers in different cultivars (Gupta, 1999) and seedling trees in different walnut growing areas (Pandey and Sinha, 1984; Rathore, 1984; Singh, 1993 and Sharma and Sharma, 1997a, 1998b, 2000b, 2001). It may be recalled that extremely high kernel percentage is because of extra thin shells which is not a highly desirable trait from marketing view point. Light colour is a primary selection criterion for kernel quality and in general, colour ranges from very light (amber coloured) to dark brown. This trait though influenced by environment to some extent, is cultivar specific. So much so that a selection with red coloured kernels was reported (Krusmann, 1984). The identification of as many 24 seedling trees bearing nuts with very light to light brown kernels suggests the scope of making selections for this desirable character.

Many genotypes (15 seedling trees) have been found to have easily removable kernels, an extremely important and desirable trait from consumer and industry point of view. Amongst the promising types, the easily removable kernels were found in the seedling tree selections namely, SS-3, SS-31, SS-36, SS-51, SS-53, SS-54 and SS-55.

5.3 CHEMICAL ANALYSIS

In the present study fat content ranged from 32.7 per cent in SS-54 to 68.7 per cent in SS-43 and protein content ranged from 9.00 per cent in SS-8 to 17.36 per cent in SS-56 (Table 7). Reported range of fat content varies between 41.78 per cent to 74.83 per cent in different selections of seedling origin (Ermakov and Sharova, 1972; Singh, 1993; Strila *et al.*, 1988; Sharma, 1999). Gupta (1999) reported 62.08 per cent fats in the kernels of 'Solding Selection', whereas, reports indicated the range of protein content in kernels varying from 6.47 to 20.52 per cent (Ermakov and Sharova, 1972; Kropp *et al.*, 1972; Furuuchi *et al.*, 1981; Bugarcic *et al.*, 1985; Sharma, 1979; Sen, 1983; Singh, 1993; Mitrovic *et al.*, 1997; Sharma and Sharma, 1997b, 2000b; Yarilgac *et al.*, 2001).

From the foregoing discussion on characterization and evaluation and considering important horticultural characters, different walnut selections have been identified as gene sources for one or more such traits which are enlisted in Table 11. Although not even a single selection was found to excel for all the traits, yet as many as 12 walnut tree selections have been rated as promising (Table 12) based upon their overall performance and selection SS-51 (Fig.10) has been found to be outstanding out of the lot. It may be worthwhile to suggest that these promising selections should be multiplied vegetatively and evaluated further under varied agro-climatic conditions in Himachal Pradesh.

5.4 CORRELATION AND PATH ANALYSIS

Significant correlation at phenotypic level have been observed between most of the tree, foliage, floral, nut and kernel characteristics (Table 9) in the present study. Hansche *et al.* (1972) observed high positive correlations between leafing, flowering

Table 11 : List of walnut selections (gene sources) for some desirable horticultural traits

1.	Late leafing time (2 nd week April onwards)	SS-14, SS-15, SS-51, SS-56, SS-57
2.	Yield (≥ 40 kg/tree)	SS-23, SS-24, SS-26, SS-27, SS-51, SS-52, SS-53, SS-54, SS-55
3.	Yield efficiency (> 0.05 kg/cm ²)	SS-2, SS-4, SS-6, SS-7, SS-8, SS-9, SS-10, SS-12, SS-23, SS-24, SS-30, SS-31, SS-40
4.	Degree of dichogamy (< 25%)	SS-13, SS-18, SS-24, SS-26, SS-51, SS-52, SS-53, SS-54, SS-55
5.	Female flower abundance (Heavy)	SS-23, SS-24, SS-26, SS-27, SS-40, SS-51, SS-52, SS-53, SS-54, SS-55
6.	Inshell nut weight (≥ 12 g)	SS-17, SS-24, SS-25, SS-32, SS-35, SS-36, SS-39, SS-41, SS-42, SS-46, SS-51, SS-52, SS-54, SS-55, SS-57
7.	Shell texture (Smooth)	SS-2, SS-29, SS-43
8.	Shell thickness (≤ 1.75 mm)	SS-5, SS-9, SS-12, SS-16, SS-33, SS-35
9.	Kernel percentage ($\geq 45\%$)	SS-2, SS-31, SS-38, SS-40, SS-44, SS-49, SS-51, SS-52, SS-53
10.	Kernel fat percentage ($\geq 55\%$)	SS-3, SS-8, SS-35, SS-38, SS-43, SS-51

Table 12 : Promising walnut selections

Selection No.	Distinguishing characteristics
SS-2	Yield efficiency (0.266 kg/cm ²), 2150 nuts/tree, shell texture smooth, shell seal strong, shelling percentage (45.25%)
SS-3	Homogamous (30.77 %), yield efficiency (0.030 kg/cm ²), shell seal strong, shelling percentage (43.10 %), fat percentage (59.85 %)
SS-17	Yield efficiency (0.036 kg/cm ²), homogamous ^{Protandrous} (50%), nut weight (15.25 g), kernel percentage (43.28 %), kernel colour light, fat percentage (48.45 %)
SS-31	Yield efficiency (0.102 kg/cm ²), 2212 nuts/tree, shell seal strong, shell thickness (1.86 mm), easy kernel removal, kernel percentage (45.96 %), fat percentage (52.40 %)
SS-36	Nut weight (14.30 g), easy kernel removal, kernel percentage (40.56 %), kernel fat (47.50 %)
SS-41	Shell seal strong, shell thickness (1.94 mm), nut weight (12.30 g), kernel percentage (41.87 %), kernel colour light, fat percentage (45.95%)
SS-46	Nut weight (14.45 g), kernel percentage (42.91%), kernel fat (54.60%),
SS-51	Yield (60.50 kg/tree), homogamous (13.33%), late leafing (7 th April), nut weight (14.65g), easy kernel removal, kernel percentage (46.42%), kernel colour light, fat percentage (66.50%)
SS-52	Yield (40.50 kg/tree), homogamous (23.08 %), nut weight (13.20g), shell seal strong, kernel percentage (45.83%), kernel colour light
SS-53	Yield (46.75 kg/tree), homogamous (14.29%), easy kernel removal, kernel percentage (47.14%), fat percentage (53.25%)
SS-54	Yield (49 kg/tree), homogamous (20.00%), nut weight (13.65g), easy kernel removal, kernel percentage (44.69%), kernel colour light
SS-55	Yield (50.50 kg/tree), homogamous (15.38%), shell seal strong, nut weight (14.00g), easy kernel removal, kernel percentage (44.64%), kernel fat (50.75%)



Fig. 10: SS-51

and harvest dates, whereas in the present study, no significant correlation was recorded between leafing and harvesting time. The present findings also did not coincide with the reports of Bugarcic *et al.* (1985) who observed very early or very late leafing time to be associated with higher yield, and also early leafing forms produced largest nuts. Highly positive and significant correlations were observed between tree yield and trunk girth and trunk cross-sectional area but significant and negative correlation with degree of dichogamy. This suggests that to obtain higher yield, emphasis should be given on selecting vigorous and homogamous types. In-shell nut weight also showed positive association with trunk girth, trunk cross-sectional area and yield (Table 9) but its indirect positive effect on yield was more pronounced via kernel weight. The association of yield with trunk girth and trunk cross-sectional area is a true relationship as evident from direct and positive effects of these two characters on yield (Table 10).

On the whole, it may not be possible to substantiate the present findings with earlier works considering the small sample size and inclusion of different characters for correlation studied here. Nevertheless, in-shell nut weight, trunk girth, trunk cross-sectional area, late leafing time and tendency towards homogamy could be suitable criteria for future selection studies.

Chapter-6
SUMMARY

SUMMARY

The present investigation entitled "Selecting walnuts from seedling tree populations in some villages of district Sirmour (H.P.)" was undertaken during 2001-2002. A total of 57 walnut trees of seedling origin growing in Deedag, Chauras, Khal, Gandoori and Chikhria village were included for comprehensive characterization and evaluation studies. The salient results obtained are summarized as under:

Considerable variation was observed for various metric tree, foliage, flowering, nut and kernel characters in all the 57 trees studied here. The notable examples are: trunk girth (26.0-308.0 cm), trunk cross sectional area (53.82-7546.80 cm²), yield (2.75-60.5 kg/tree), number of nuts (234-5505 nuts/tree), yield efficiency (0.007-0.266 kg/cm²), leafing time (19th March-13th April), degree of dichogamy (10-100%), in-shell nut weight (6.75-16.10g), shell thickness (1.61-3.02 mm), kernel percentage (28.89-53.55%), fat content (32.70-68.70%) and protein content (9.00-17.36%). Likewise, variation was observed for non-metric characteristics viz. tree growth habit (erect, semi-erect, spreading), nature of dichogamy (homogamous, protandrous), shell texture (smooth, intermediate, rough, very rough), nut shape (circular, trapezoid, elliptic, ovate, broad elliptic, obovate, triangular, cordate) and kernel colour (very light, light, medium, dark).

No variation was observed for bearing habit (only terminal bearer) and shell integrity (all exhibit complete shell integrity). Correlation and path analysis suggested that in-shell nut weight, trunk girth, trunk cross-sectional area, late leafing time and low degree of dichogamy could be suitable criteria for future selection studies. The yield was maximum (60.5 kg/tree) in SS-51, yield efficiency (0.266 kg/cm²) in SS-2,

in-shell nut weight (16.10 g) in SS-57, fat content (68.70%) in SS-43 and protein content (17.36%) in SS-56. Whereas minimum shell thickness (1.61 mm) was recorded in SS-12. Nine selections (SS-13, SS-18, SS-24, SS-26, SS-51, SS-52, SS-53, SS-54, SS-55) were found to be homogamous having less than 25 per cent degree of dichogamy and SS-57 was last to show the leaf bud burst on 13th April.

None of the seedling trees selected were found to be good in all desirable horticultural traits. But still there are some 12 walnut trees, excelling over others in one or more desirable horticultural traits. These are SS-2, SS-3, SS-17, SS-31, SS-36, SS-41, SS-46, SS-51, SS-52, SS-53, SS-54 and SS-55 which may be tested under varied agro-climatic conditions of Himachal Pradesh. SS-51, on the whole, has been found to be outstanding in terms of growth, yield, nut and kernel quality.

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APPENDICES

Appendix-I
Extent of variation in tree and foliage characters (non-metric) of walnut trees of seedling origin
in some villages of district Sirmour (H.P.)

Selection No.	Growth habit	Branching density	Shoot pubescence	Shoot colour	Leaf colour	Rachis colour	Leaf and rachis pubescence	Leaf for rachis persistence
SS-1	Semi erect	Medium	Glabrous	Green brown	Dark green	Green	Slightly pubescent	Few remain attached
SS-2	Semi erect	Sparse	Glabrous	Blackish	Dark green	Yellow	Slightly pubescent	Intermediate
SS-3	Semi erect	Dense	Glabrous	Green brown	Dark green	Red	Slightly pubescent	Few remain attached
SS-4	Spreading	Dense	Glabrous	Blackish	Green	Green	Slightly pubescent	Intermediate
SS-5	Semi erect	Dense	Slightly pubescent	Blackish	Light green	Yellow	Slightly pubescent	Intermediate
SS-6	Semi erect	Dense	Glabrous	Pale brown	Light green	Green	Slightly pubescent	Intermediate
SS-7	Erect	Sparse	Slightly pubescent	Blackish	Green	Green	Pubescent	Few remain attached
SS-8	Spreading	Dense	Slightly pubescent	Green brown	Dark green	Green	Slightly pubescent	Few remain attached
SS-9	Semi erect	Medium	Glabrous	Green brown	Light green	Yellow	Slightly pubescent	Intermediate
SS-10	Semi erect	Medium	Glabrous	Green brown	Green	Green	Glabrous	Few remain attached
SS-11	Spreading	Dense	Glabrous	Green brown	Dark green	Green	Glabrous	Few remain attached
SS-12	Semi erect	Dense	Slightly pubescent	Blackish	Green	Green	Glabrous	Intermediate
SS-13	Spreading	Dense	Slightly pubescent	Green brown	Green	Green	Slightly pubescent	Intermediate
SS-14	Semi erect	Dense	Glabrous	Blackish	Light green	Yellow	Glabrous	Intermediate
SS-15	Spreading	Dense	Slightly pubescent	Blackish	Light green	Yellow	Slightly pubescent	Few remain attached
SS-16	Spreading	Dense	Slightly pubescent	Green brown	Green	Yellow	Glabrous	Few remain attached
SS-17	Semi erect	Medium	Slightly pubescent	Green brown	Green	Green	Slightly pubescent	Few remain attached
SS-18	Semi erect	Dense	Slightly pubescent	Green brown	Green	Yellow	Slightly pubescent	Few remain attached
SS-19	Spreading	Dense	Glabrous	Green brown	Green	Green	Slightly pubescent	Intermediate
SS-20	Spreading	Dense	Slightly pubescent	Green brown	Green	Green	Slightly pubescent	Few remain attached
SS-21	Spreading	Dense	Glabrous	Blackish	Green	Green	Slightly pubescent	Few remain attached
SS-22	Spreading	Medium	Slightly pubescent	Green brown	Dark green	Red	Slightly pubescent	Few remain attached
SS-23	Spreading	Dense	Glabrous	Blackish	Dark green	Green	Pubescent	Few remain attached
SS-24	Spreading	Dense	Slightly pubescent	Green brown	Green	Green	Slightly pubescent	Intermediate
SS-25	Spreading	Dense	Slightly pubescent	Green brown	Green	Green	Slightly pubescent	Intermediate
SS-26	Spreading	Dense	Slightly pubescent	Green brown	Dark green	Red	Slightly pubescent	Intermediate
SS-27	Spreading	Dense	Slightly pubescent	Green brown	Dark green	Green	Slightly pubescent	Intermediate
SS-28	Spreading	Dense	Slightly pubescent	Green brown	Dark green	Green	Slightly pubescent	Few remain attached
SS-29	Spreading	Dense	Slightly pubescent	Blackish	Green	Green	Glabrous	Intermediate
SS-30	Semi erect	Medium	Slightly pubescent	Blackish	Green	Green	Slightly pubescent	Few remain attached
SS-31	Semi erect	Dense	Slightly pubescent	Green brown	Dark green	Green	Slightly pubescent	Few remain attached
SS-32	Semi erect	Medium	Glabrous	Blackish	Green	Green	Slightly pubescent	Few remain attached
SS-33	Semi erect	Dense	Slightly pubescent	Green brown	Dark green	Green	Slightly pubescent	Intermediate
SS-34	Spreading	Dense	Slightly pubescent	Blackish	Green	Red	Slightly pubescent	Intermediate
SS-35	Spreading	Medium	Slightly pubescent	Green brown	Dark green	Yellow	Slightly pubescent	Intermediate
SS-36	Spreading	Dense	Slightly pubescent	Blackish	Light green	Yellow	Slightly pubescent	Intermediate
SS-37	Spreading	Dense	Slightly pubescent	Green brown	Green	Green	Slightly pubescent	Few remain attached
SS-38	Spreading	Dense	Slightly pubescent	Blackish	Light green	Yellow	Slightly pubescent	Few remain attached
SS-39	Spreading	Dense	Slightly pubescent	Green brown	Dark green	Yellow	Glabrous	Few remain attached
SS-40	Spreading	Dense	Slightly pubescent	Pale brown	Green	Green	Glabrous	Few remain attached
SS-41	Spreading	Dense	Pubescent	Blackish	Green	Green	Glabrous	Intermediate
SS-42	Semi erect	Sparse	Slightly pubescent	Blackish	Green	Red	Glabrous	Few remain attached
SS-43	Semi erect	Medium	Slightly pubescent	Pale brown	Green	Green	Slightly pubescent	Few remain attached
SS-44	Semi erect	Dense	Slightly pubescent	Green brown	Green	Red	Slightly pubescent	Few remain attached
SS-45	Semi erect	Medium	Slightly pubescent	Blackish	Green	Green	Slightly pubescent	Intermediate
SS-46	Spreading	Medium	Slightly pubescent	Pale brown	Green	Yellow	Slightly pubescent	Few remain attached
SS-47	Spreading	Medium	Slightly pubescent	Green brown	Dark green	Yellow	Slightly pubescent	Few remain attached
SS-48	Semi erect	Medium	Slightly pubescent	Green brown	Dark green	Red	Pubescent	Few remain attached
SS-49	Semi erect	Medium	Slightly pubescent	Blackish	Green	Yellow	Slightly pubescent	Few remain attached
SS-50	Semi erect	Dense	Slightly pubescent	Pale brown	Green	Green	Slightly pubescent	Few remain attached
SS-51	Spreading	Dense	Slightly pubescent	Green brown	Dark green	Green	Glabrous	Intermediate
SS-52	Spreading	Dense	Slightly pubescent	Green brown	Green	Red	Slightly pubescent	Intermediate
SS-53	Spreading	Dense	Slightly pubescent	Green brown	Dark green	Green	Slightly pubescent	Intermediate
SS-54	Spreading	Medium	Glabrous	Green brown	Green	Red	Slightly pubescent	Few remain attached
SS-55	Spreading	Medium	Glabrous	Blackish	Green	Red	Slightly pubescent	Intermediate
SS-56	Semi erect	Medium	Glabrous	Green brown	Dark green	Green	Glabrous	Few remain attached
SS-57	Spreading	Dense	Glabrous	Green brown	Dark green	Green	Glabrous	Few remain attached

SS - Sirmour Selection

Appendix-II

Extent of variation in floral and fruiting characters (non-metric) of walnut trees of seedling origin in some villages of district Sirmour (H.P.)

Selection No.	Dichogamy	Bearing habit	Female flower abundance	Stigma colour	Hull persistence after nut fall	Hull dehiscence	Peak male bloom date	Peak female bloom date
SS-1	Protandrous	Terminal	Light	Yellow	Slight	Dehiscent	29/3	1/4
SS-2	Protandrous	Terminal	Intermediate	Yellow	Slight	Dehiscent	6/4	14/4
SS-3	Protandrous	Terminal	Intermediate	Red	Slight	Dehiscent	9/4	11/4
SS-4	Protandrous	Terminal	Intermediate	Yellow	Slight	Dehiscent	3/4	12/4
SS-5	Protandrous	Terminal	Intermediate	Red	Moderate	Slightly Dehiscent	1/4	10/4
SS-6	Protandrous	Terminal	Intermediate	Yellow	Moderate	Dehiscent	4/4	11/4
SS-7	Protandrous	Terminal	Light	Yellow	Slight	Dehiscent	1/4	17/4
SS-8	Protandrous	Terminal	Intermediate	Yellow	Slight	Dehiscent	3/4	13/4
SS-9	Protandrous	Terminal	Intermediate	Red	Slight	Dehiscent	10/4	14/4
SS-10	Protandrous	Terminal	Intermediate	Yellow	Slight	Dehiscent	6/4	10/4
SS-11	Protandrous	Terminal	Intermediate	Red	Moderate	Dehiscent	3/4	10/4
SS-12	Protandrous	Terminal	Light	Yellow	Slight	Slightly Dehiscent	3/4	10/4
SS-13	Homogamous	Terminal	Intermediate	Red	Slight	Slightly Dehiscent	2/4	5/4
SS-14	Protandrous	Terminal	Light	Yellow	Slight	Dehiscent	16/4	21/4
SS-15	Protandrous	Terminal	Intermediate	Yellow	Slight	Dehiscent	15/4	18/4
SS-16	Protandrous	Terminal	Intermediate	Red	Slight	Dehiscent	4/4	10/4
SS-17	Protandrous	Terminal	Intermediate	Yellow	Slight	Dehiscent	8/4	12/4
SS-18	Homogamous	Terminal	Intermediate	Yellow	Moderate	Dehiscent	10/4	12/4
SS-19	Protandrous	Terminal	Intermediate	Yellow	Slight	Dehiscent	11/4	20/4
SS-20	Protandrous	Terminal	Intermediate	Yellow	Slight	Dehiscent	16/4	22/4
SS-21	Protandrous	Terminal	Light	Red	Moderate	Dehiscent	5/4	12/4
SS-22	Protandrous	Terminal	Light	Yellow	Slight	Dehiscent	3/4	13/4
SS-23	Protandrous	Terminal	Heavy	Yellow	Slight	Dehiscent	9/4	12/4
SS-24	Homogamous	Terminal	Heavy	Red	Slight	Dehiscent	10/4	12/4
SS-25	Protandrous	Terminal	Intermediate	Yellow	Slight	Dehiscent	15/4	12/4
SS-26	Homogamous	Terminal	Heavy	Red	Moderate	Dehiscent	6/4	10/4
SS-27	Protandrous	Terminal	Heavy	Yellow	Slight	Slightly Dehiscent	6/4	10/4
SS-28	Protandrous	Terminal	Intermediate	Red	Slight	Slightly Dehiscent	5/4	10/4
SS-29	Protandrous	Terminal	Intermediate	Yellow	Slight	Dehiscent	8/4	16/4
SS-30	Protandrous	Terminal	Intermediate	Yellow	Moderate	Slightly Dehiscent	5/4	13/4
SS-31	Protandrous	Terminal	Intermediate	Red	Slight	Dehiscent	7/4	13/4
SS-32	Protandrous	Terminal	Intermediate	Green	Slight	Dehiscent	4/4	12/4
SS-33	Protandrous	Terminal	Light	Yellow	Slight	Dehiscent	6/4	14/4
SS-34	Protandrous	Terminal	Intermediate	Green	Slight	Dehiscent	5/4	12/4
SS-35	Protandrous	Terminal	Intermediate	Red	Slight	Slightly Dehiscent	29/3	11/4
SS-36	Protandrous	Terminal	Intermediate	Yellow	Slight	Slightly Dehiscent	31/3	11/4
SS-37	Protandrous	Terminal	Light	Red	Moderate	Slightly Dehiscent	2/4	9/4
SS-38	Protandrous	Terminal	Light	Red	Slight	Dehiscent	11/4	19/4
SS-39	Protandrous	Terminal	Intermediate	Red	Moderate	Dehiscent	1/4	10/4
SS-40	Protandrous	Terminal	Heavy	Red	Moderate	Dehiscent	2/4	12/4
SS-41	Protandrous	Terminal	Intermediate	Red	Moderate	Dehiscent	2/4	9/4
SS-42	Protandrous	Terminal	Light	Red	Moderate	Dehiscent	4/4	12/4
SS-43	Protandrous	Terminal	Light	Yellow	Slight	Dehiscent	5/4	12/4
SS-44	Protandrous	Terminal	Light	Yellow	Slight	Dehiscent	30/3	8/4
SS-45	Protandrous	Terminal	Light	Green	Moderate	Dehiscent	29/3	13/4
SS-46	Protandrous	Terminal	Intermediate	Yellow	Slight	Slightly Dehiscent	1/4	15/4
SS-47	Protandrous	Terminal	Light	Yellow	Slight	Dehiscent	2/4	12/4
SS-48	Protandrous	Terminal	Light	Yellow	Moderate	Dehiscent	4/4	12/4
SS-49	Protandrous	Terminal	Light	Yellow	Slight	Dehiscent	7/4	13/4
SS-50	Protandrous	Terminal	Intermediate	Red	Slight	Slightly Dehiscent	2/4	11/4
SS-51	Homogamous	Terminal	Heavy	Yellow	Moderate	Dehiscent	9/4	10/4
SS-52	Homogamous	Terminal	Heavy	Yellow	Moderate	Dehiscent	3/4	9/4
SS-53	Homogamous	Terminal	Heavy	Red	Slight	Dehiscent	1/4	2/4
SS-54	Homogamous	Terminal	Heavy	Red	Moderate	Dehiscent	2/4	7/4
SS-55	Homogamous	Terminal	Heavy	Yellow	Moderate	Slightly Dehiscent	3/4	6/4
SS-56	Protandrous	Terminal	Intermediate	Green	Slight	Slightly Dehiscent	17/4	22/4
SS-57	Protandrous	Terminal	Intermediate	Green	Slight	Slightly Dehiscent	17/4	23/4

SS - Sirmour Selection

Appendix-III

Extent of variation in nut and kernel characters (non-metric) of walnut trees of seedling origin in some villages of district Sirmour (H.P.)

Selection No.	Nut shape		Shell texture	Shell colour	Shell seal	Shell strength	Shell integrity	Kernel colour	Kernel fill	Kernel plumpness	Ease of removal of kernel halves
	Through suture	Perpendicular to suture									
SS-1	Circular	Circular	Medium	Light	Intermediate	Strong	Complete	Medium	Moderate	Thin	Moderate
SS-2	Circular	Circular	Smooth	Medium	Strong	Intermediate	Complete	Medium	Well	Moderate	Moderate
SS-3	Ovate	Trapezoid	Medium	Light	Strong	Strong	Complete	Medium	Well	Moderate	Easy
SS-4	Circular	Ovate	Medium	Medium	Weak	Intermediate	Complete	Dark	Well	Moderate	Moderate
SS-5	Elliptic	Circular	Medium	Medium	Strong	Strong	Complete	Dark	Well	Moderate	Moderate
SS-6	Circular	Circular	Rough	Medium	Intermediate	Strong	Complete	Light	Well	Moderate	Easy
SS-7	Elliptic	Circular	Medium	Light	Strong	Strong	Complete	Medium	Well	Thin	Moderate
SS-8	Circular	Circular	Medium	Medium	Strong	Strong	Complete	Very light	Moderate	Thin	Difficult
SS-9	Circular	Circular	Rough	Medium	Intermediate	Strong	Complete	Medium	Well	Thin	Moderate
SS-10	Ovate	Circular	Rough	Medium	Strong	Strong	Complete	Light	Well	Moderate	Easy
SS-11	Circular	Trapezoid	Medium	Light	Intermediate	Intermediate	Complete	Dark	Well	Thin	Difficult
SS-12	Ovate	Trapezoid	Medium	Medium	Strong	Strong	Complete	Dark	Well	Moderate	Moderate
SS-13	Circular	Circular	Medium	Light	Strong	Strong	Complete	Light	Well	Thin	Moderate
SS-14	Ovate	Trapezoid	Rough	Very dark	Strong	Strong	Complete	Light	Well	Moderate	Moderate
SS-15	Ovate	Circular	Medium	Medium	Intermediate	Strong	Complete	Dark	Moderate	Thin	Moderate
SS-16	Circular	Circular	Rough	Medium	Intermediate	Strong	Complete	Medium	Well	Thin	Moderate
SS-17	Ovate	Ovate	Medium	Light	Weak	Strong	Complete	Light	Well	Moderate	Moderate
SS-18	Ovate	Trapezoid	Rough	Dark	Strong	Strong	Complete	Light	Moderate	Thin	Moderate
SS-19	Circular	Circular	Medium	Light	Intermediate	Strong	Complete	Dark	Well	Moderate	Difficult
SS-20	Obovate	Obovate	Medium	Medium	Weak	Intermediate	Complete	Light	Thin	Moderate	Difficult
SS-21	Elliptic	Elliptic	Medium	Medium	Strong	Intermediate	Complete	Medium	Well	Thin	Moderate
SS-22	Ovate	Ovate	Medium	Light	Strong	Intermediate	Complete	Light	Well	Thin	Difficult
SS-23	Triangular	Trapezoid	Rough	Dark	Strong	Intermediate	Complete	Dark	Well	Moderate	Moderate
SS-24	Trapezoid	Trapezoid	Rough	Dark	Intermediate	Intermediate	Complete	Dark	Moderate	Thin	Moderate
SS-25	Circular	Trapezoid	Very rough	Dark	Strong	Intermediate	Complete	Medium	Well	Thin	Difficult
SS-26	Elliptic	Elliptic	Rough	Medium	Strong	Intermediate	Complete	Light	Moderate	Moderate	Easy
SS-27	Circular	Circular	Rough	Medium	Intermediate	Intermediate	Complete	Light	Well	Moderate	Moderate
SS-28	Elliptic	Elliptic	Medium	Dark	Strong	Intermediate	Complete	Medium	Moderate	Thin	Difficult
SS-29	Elliptic	Elliptic	Smooth	Light	Weak	Intermediate	Complete	Dark	Well	Thin	Easy
SS-30	Trapezoid	Ovate	Rough	Light	Intermediate	Strong	Complete	Medium	Well	Moderate	Moderate
SS-31	Elliptic	Elliptic	Medium	Very light	Strong	Strong	Complete	Medium	Well	Moderate	Easy
SS-32	Ovate	Circular	Rough	Medium	Intermediate	Strong	Complete	Light	Moderate	Moderate	Very difficult
SS-33	Elliptic	Obovate	Medium	Light	Intermediate	Weak	Complete	Light	Moderate	Moderate	Moderate
SS-34	Ovate	Trapezoid	Rough	Medium	Strong	Strong	Complete	Dark	Moderate	Thin	Moderate
SS-35	Triangular	Cordate	Rough	Medium	Intermediate	Strong	Complete	Medium	Well	Thin	Easy
SS-36	Broad elliptic	Elliptic	Medium	Light	Intermediate	Strong	Complete	Medium	Moderate	Thin	Easy
SS-37	Ovate	Circular	Medium	Medium	Strong	Strong	Complete	Medium	Well	Moderate	Difficult
SS-38	Ovate	Circular	Medium	Light	Strong	Strong	Complete	Dark	Moderate	Moderate	Moderate
SS-39	Circular	Circular	Medium	Medium	Strong	Strong	Complete	Dark	Well	Thin	Moderate
SS-40	Trapezoid	Trapezoid	Medium	Light	Strong	Strong	Complete	Medium	Well	Moderate	Easy
SS-41	Trapezoid	Trapezoid	Medium	Light	Strong	Strong	Complete	Medium	Well	Moderate	Moderate
SS-42	Circular	Circular	Very rough	Dark	Strong	Strong	Complete	Very light	Well	Moderate	Moderate
SS-43	Ovate	Ovate	Smooth	Medium	Strong	Strong	Complete	Medium	Well	Moderate	Moderate
SS-44	Circular	Trapezoid	Rough	Medium	Strong	Strong	Complete	Dark	Well	Moderate	Moderate
SS-45	Circular	Circular	Medium	Medium	Weak	Intermediate	Complete	Dark	Well	Moderate	Easy
SS-46	Broad elliptic	Circular	Rough	Dark	Weak	Weak	Complete	Dark	Well	Thin	Moderate
SS-47	Triangular	Circular	Medium	Light	Strong	Strong	Complete	Dark	Moderate	Thin	Moderate
SS-48	Circular	Circular	Medium	Light	Intermediate	Strong	Complete	Dark	Moderate	Thin	Difficult
SS-49	Broad elliptic	Circular	Rough	Light	Weak	Intermediate	Complete	Dark	Well	Moderate	Moderate
SS-50	Ovate	Ovate	Rough	Very light	Strong	Strong	Complete	Light	Well	Moderate	Easy
SS-51	Trapezoid	Trapezoid	Medium	Light	Intermediate	Weak	Complete	Light	Well	Moderate	Easy
SS-52	Ovate	Trapezoid	Rough	Dark	Strong	Strong	Complete	Medium	Well	Moderate	Moderate
SS-53	Ovate	Ovate	Very rough	Very dark	Intermediate	Intermediate	Complete	Light	Well	Moderate	Easy
SS-54	Ovate	Ovate	Very rough	Dark	Intermediate	Strong	Complete	Light	Well	Moderate	Easy
SS-55	Broad elliptic	Trapezoid	Very rough	Medium	Strong	Strong	Complete	Medium	Well	Moderate	Easy
SS-56	Ovate	Trapezoid	Very rough	Medium	Strong	Strong	Complete	Light	Moderate	Thin	Very difficult
SS-57	Elliptic	Obovate	Very rough	Medium	Strong	Strong	Complete	Medium	Well	Thin	Moderate

SS - Sirmour Selection

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B.Sc. - N/A
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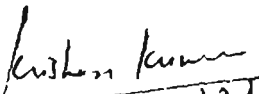
Year of Award of Degree : **2002**


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Abstract

The present studies were undertaken to select superior walnuts from existing seedling tree populations in Deedag, Chauras, Chikhria, Khal and Gandoori villages of district Sirmour, Himachal Pradesh. Out of a total of 342 trees screened, only 57 trees were found to be regular in bearing and had good nut and kernel characteristics. These selected 57 trees were subjected to comprehensive characterization and evaluation studies to identify superior genotypes. All the selected trees showed considerable variation in growth, floral, yield and quality characters. However, no variation was recorded for characters like terminal bearing and completeness of nut shell. The yield was maximum (60.5 kg/tree) in SS-51, yield efficiency (0.266 kg/cm²) in SS-2, in-shell nut weight (16.10 g) in SS-57, fat content (68.70 %) in SS-43 and protein content (17.36 %) in SS-56 whereas minimum shell thickness (1.61 mm) was recorded in SS-12. Nine selections (SS-13, SS-18, SS-24, SS-26, SS-51, SS-52, SS-53, SS-54, SS-55) were found to be homogamous having less than 25 percent degree of dichogamy and SS-57 was last to show the leaf bud burst on 13th April. None of the seedling trees selected were found to be good in all desirable horticultural traits. But still there are some 12 walnut trees, excelling over others in one or more desirable horticultural traits. These are SS-2, SS-3, SS-17, SS-31, SS-36, SS-41, SS-46, SS-51, SS-52, SS-53, SS-54 and SS-55 which may be tested under varied agro-climatic conditions of Himachal Pradesh. SS-51, on the whole, has been found to be outstanding in terms of growth, yield, nut and kernel quality. Correlation and path analysis suggested that in-shell nut weight, trunk girth, trunk cross-sectional area, late leafing time and low degree of dichogamy could be suitable criteria for future selection studies.


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