Adv. Hort. Sci., 2013 27(1-2): 61-66

Protandrous-protogynous dimorphism in indigenous selections from North Western India and some exotic cultivars of Persian walnut (*Juglans regia* L.)

A. Kumar*, N. Sharma**

* *Division of Fruit Science, Sher-e-Kashmir University Agricultural Sciences and Technology, Kashmir, Shalimar, Srinagar, Jammu and Kashmir, India.*

** *Division of Fruit Science, Sher-e-Kashmire University Agricoltural Sciences and Tecnology, Jammu, Chatta, Jammu, Jammy and Kashmir, India.*

Key words: dichogamy, low productivity, pollen shedding, stigma receptivity, walnut.

Abstract: Walnut (*Juglans regia* L.) is one of the most important temperate nuts grown worldwide. In India, however, most of the produce comes from age-old trees of unknown origin. Apart from non-adoption of standard farm practices, certain inherent problems like dichogamy are the major factors of low productivity. The problem of dichogamy is further aggravated by short period of pollen shedding and stigma receptivity. Dichogamy in walnut prevents self-pollination and necessitates cross-pollination to set fruits. For optimum fruit set and consequent yield, an attempt was made with 20 cultivars/selections grafted on seedling walnuts for three consecutive years to determine the nature and degree of dichogamy. Observations were recorded on the time of male and female flowering, duration of pollen shedding and stigma receptivity, nature and degree of dichogamy. Results indicate that out of 20 cultivars/selections fourteen have protandrous nature, 'Gobind' in the first and third year, 'KX Giant' in second and third year and 'Plant No. 45' in the second year have homogamous nature and only 'Gobind' have protogynous nature in the second year. Degree of dichogamy varies from zero to 100 per cent among various cultivars/selections. Findings of the present study emphasized on the interplanting of protandrous and protogynous cultivars or homogamous cultivars to ensure adequate pollination to obtain higher nut yields in walnut.

1. Introduction

Juglans regia plants are monoecious, anemophilous with unisexual flowers grouped in separate inflorescences (Manning, 1938; Bauckmann, 1974; Germain *et al*., 1981). Staminate flowers (catkins) develop from lateral buds in the axil of leaves on the previous season's growth. Pistillate flowers are borne terminally on the current season's growth, however in some cultivars, also develops in a lateral position on the last year's growth (Forde, 1977). Although *Juglans regia* cultivars are self fertile, but low yields in walnut is a cause of concern which is mainly attributed to inadequate pollination resulting from pistillate flower abscission (PFA) and adverse climatic conditions during pollen shedding and stigma receptivity. Apart from these factors, dichogamy is also a main cause for low yields in walnut which was steady and biological characteristics of walnut (Akca and Sen, 1997).

The phenomenon of dichogamy involves development on the same plant of male and female organs at different times. 'Protandry' refers to the shedding of pollen prior to stigma receptivity and 'protogyny' the reverse sequence (Gleeson, 1982). The mating system with both protandrous and protogynous plants within the species has been classified as heterodichogamy (Gleeson, 1982; Luza and Polito, 1988). The extent of heterodichogamy varies from almost complete overlap (homogamy) to complete separation of male and female bloom periods (McGranahan and Leslie, 1991). The degree and nature of dichogamy is a varietal character, but it is also greatly affected by the age of the tree, climate and geographic location (Wood, 1932). Walnut variety or locality is free from dichogamy. On the basis of these data it is possible to make combinations of cultivars, which ensure pollinating and enable regular harvest. The present work deals with protandrous-protogynous dimorphism in 20 walnut cultivars/selections. To overcome the problem of low yields and to identify suitable cultivars that can overlap in blooming time, the present study was conducted at the University of Horticulture and Forestry, Nauni-Solan for three consecutive years. On this basis we can define the most suitable combinations of cultivars for north-western region of India.

Received for publication 20 March 2013
Accepted for publication 24 April 2013

2. Materials and Methods

The present study was carried out over a three-year period (2006-2008) in the walnut germplasm collection block of the Department of Fruit Breeding and Genetic Resources, Dr. Y S Parmar University of Horticulture and Forestry, Nauni-Solan, Himachal Pradesh. The walnut block is located at an elevation of 1225 m a.m.s.l. and between 31°N latitude and 77°E longitude. The mean average rainfall of the study area during the flowering season (February to April) ranges from 125 to 200 mm. The minimum and maximum temperatures of the field area during the flowering season range between 10 and 30°C. The experiment was conducted with the following 20 cultivars/selections: 'ACO 38853', 'Blackmore', 'Gobind', 'Hartley', 'Plant No.10', 'Netar Akhrot', 'Roopa Akhrot', 'KX Giant', 'Rattan Akhrot', 'Lake English', 'Kandaghat Selection', 'Payne', 'Inder Akhrot', 'Plant No. 32', 'Xenia', 'Plant No. 45', 'Plant No. 46', 'Plant No. 47', 'Solding Selection' and 'Luxmi Akhrot'. These cultivars/selections were grafted on walnut seedlings and the age of the planting material during the study was 18-20 years old. The grafted plants were planted at a distance of 7x7 m and standard practices of orchard management were followed. Observations were taken with regard to time of male and female flowering, duration of pollen shedding and stigma receptivity, nature and degree of dichogamy. Nature of dichogamy was determined as

Protandry: Maturation of male catkins prior to stigma receptivity of female flower

Protogyny: Stigma receptivity prior to maturation of male catkins

Homogamy: Maturation of male catkins coinciding with stigma receptivity in female flowers.

Degree of dichogamy was calculated according to the formula suggested by Solar *et al*. (1997).

$$\text{Degree of dichogamy (\%)} = = 1 - \frac{\text{No. of days when male and female flowering coincides}}{\text{Number of days of female flowering}} \times 100$$

3. Results and Discussion

The results obtained from the three consecutive years of study showed variation with respect to time of male and female flowering, duration of pollen shedding and stigma receptivity, nature and degree of dichogamy. The earliest emergence of catkins in all three years was recorded in 'Plant No. 45' (i.e. 12 March, 17 March and 15 March in the first, second and third years, respectively) along with 'Luxmi Akhrot' (12 March) in the first year, and 'Netar Akhrot' and 'Inder Akhrot' (17 March) in the second year (Fig. 1). Late emergence of catkins was observed in 'Solding Selection' (25 March) in the first year; in the second and third years late emergence was observed in 'Gobind' (7 April and 28 March, respectively). 'Plant No. 45' showed early female flowering (15 March in the first year, 22 March in second and 17 March in the third), whereas late emergence of female flowering in the first year was observed in 'Rattan Akhrot' (31 March), in the second year in 'Plant No. 32' (8 April) and in the third in 'ACO 38853' and 'Luxmi Akhrot' (1 April).

Early pollen shedding in 2006 and 2008 was recorded in 'Plant No. 45' (17 March and 20 March, respectively) along with 'Hartley' and 'Luxmi Akhrot' in 2006, however, it was recorded in 'Netar Akhrot' in 2007 (24 March) (Fig. 2). As for late pollen shedding the following observations were made: 'Solding Selection' (30 March 2006) and 'Gobind' (10 April 2007 and 1 April 2008). In all three years 'Plant No. 45' had early stigma receptivity (19 March, 25 March and 21 March, respectively). However, there was late stigma receptivity in 'Rattan Akhrot' in the first year (5 April), 'Plant No. 32' and 'Xenia' in the second year (12 April) and 'ACO 38853', 'Blackmore' and 'Luxmi Akhrot' in the third year (5 April).

Regarding the nature of dichogamy, it is clear from Table 1 that 'Gobind' was found to be homogamous in the first and third years, 'KX Giant' in the second and third years and 'Plant No. 45' in the second year. However, during the study period only 'Gobind' showed a protogynous nature in the second year. While 'KX Giant', 'Plant No. 32' and 'Plant No. 45' in 2006, 'Netar Akhrot' and 'Xenia' in 2007 and again 'Plant No. 45' in 2008 revealed a slight protandrous nature. All the other cultivars were of protandrous nature in all years. 'ACO 38853', 'Blackmore', 'Hartley', 'Roopa Akhrot', 'Lake English', 'Inder Akhrot', 'Plant No. 47' and 'Luxmi Akhrot' were found to have a 100% degree of dichogamy during the course of study; 'KX Giant' and 'Plant No. 45' in the second year, and 'Gobind' in the third year showed a 0% degree of dichogamy. Other cultivars/selections had a wide range of degrees of dichogamy during the study.

From the present study it is clear that Persian walnut has a large variation with regard to nature and degree of dichogamy. The degree of dichogamy in various cultivars/selections varies from zero to 100%. It is generally assumed that protandrous cultivars are the most numerous, followed by protogynous types, while homogamous types are quite rare (McDaniel, 1957; Majackaja, 1969; Germain *et al*., 1981) as also revealed in the present study. The trend here is towards protandry with as many as fourteen protandrous cultivars/selections ('ACO 38853', 'Blackmore', 'Hartley', 'Plant No. 10', 'Roopa Akhrot', 'Rattan Akhrot', 'Lake English', 'Kandaghat Selection', 'Payne', 'Inder Akhrot', 'Plant No. 46', 'Plant No. 47', 'Solding Selection' and 'Luxmi Akhrot') as demonstrated from the extent of synchronization of male and female flowering, and especially the time of pollen shedding and stigma receptivity. 'Gobind' in the first and third years, 'KX Giant' in second and third and 'Plant No. 45' in the second year had a homogamous nature, whereas only 'Gobind' showed a protogynous nature in the second year. However, the trend towards protandry was also reported by earlier researchers. Germain *et al*. (1983 a) found among

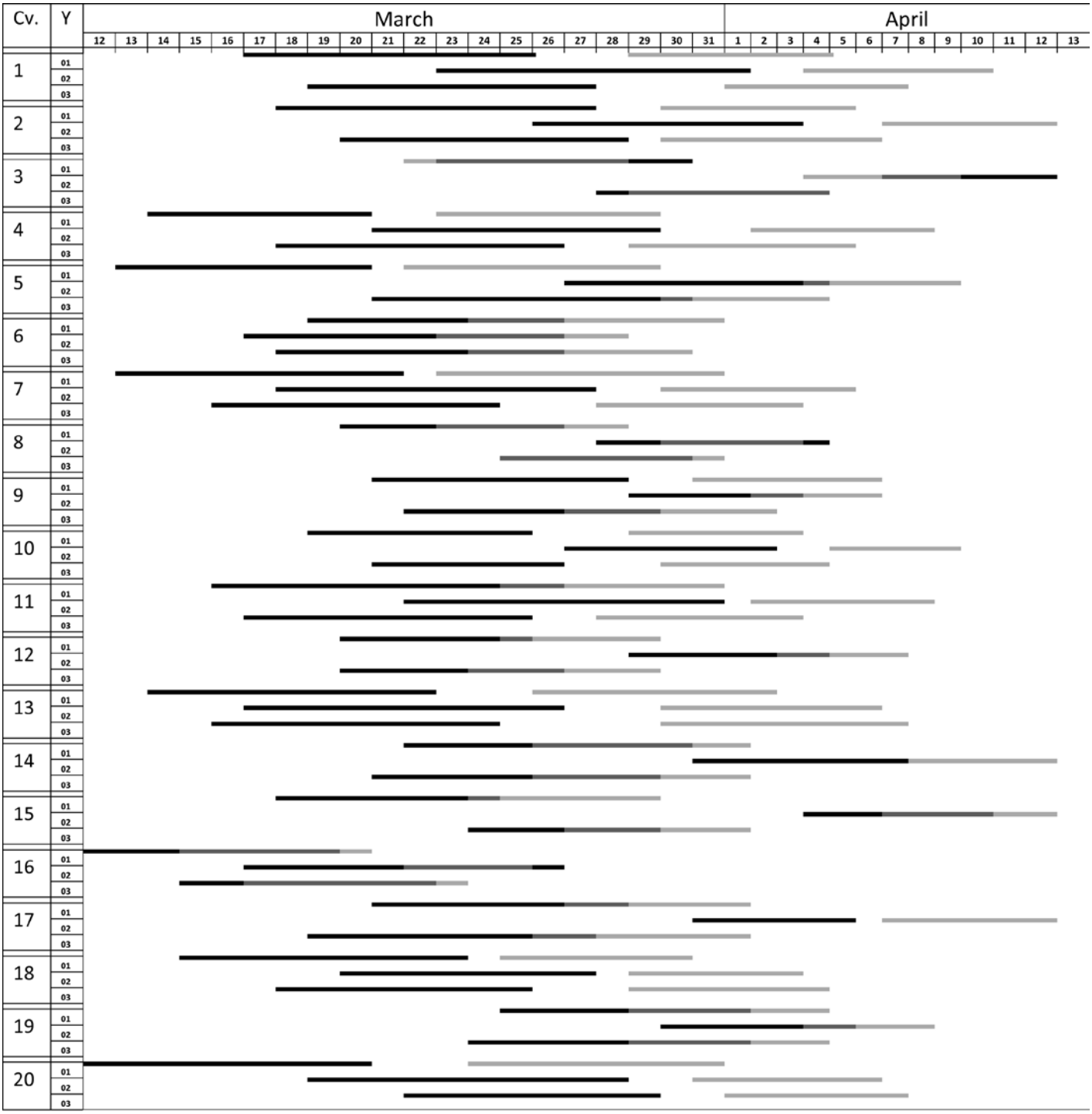

Fig. 1 - Time of male and female flowering in different walnut cultivars/selections. Cv= Cultivar; Y= Year; 01= 2006; 02= 2007; 03= 2008.

1	ACO 38853	5	Plant No. 10	9	Rattan Akhrot	13	Inder Akhrot	17	Plant No. 46
2	Blackmore	6	Netar Akhrot	10	Lake English	14	Plant No. 32	18	Plant No. 47
3	Gobind	7	Roopa Akhrot	11	Kandaghat Selection	15	Xenia	19	Solding Selection
4	Hartley	8	KX Giant	12	Payne	16	Plant No. 45	20	Luxmi Akhrot

Time of male flowering
Overlapping of male flowering and female flowering
Time of female flowering

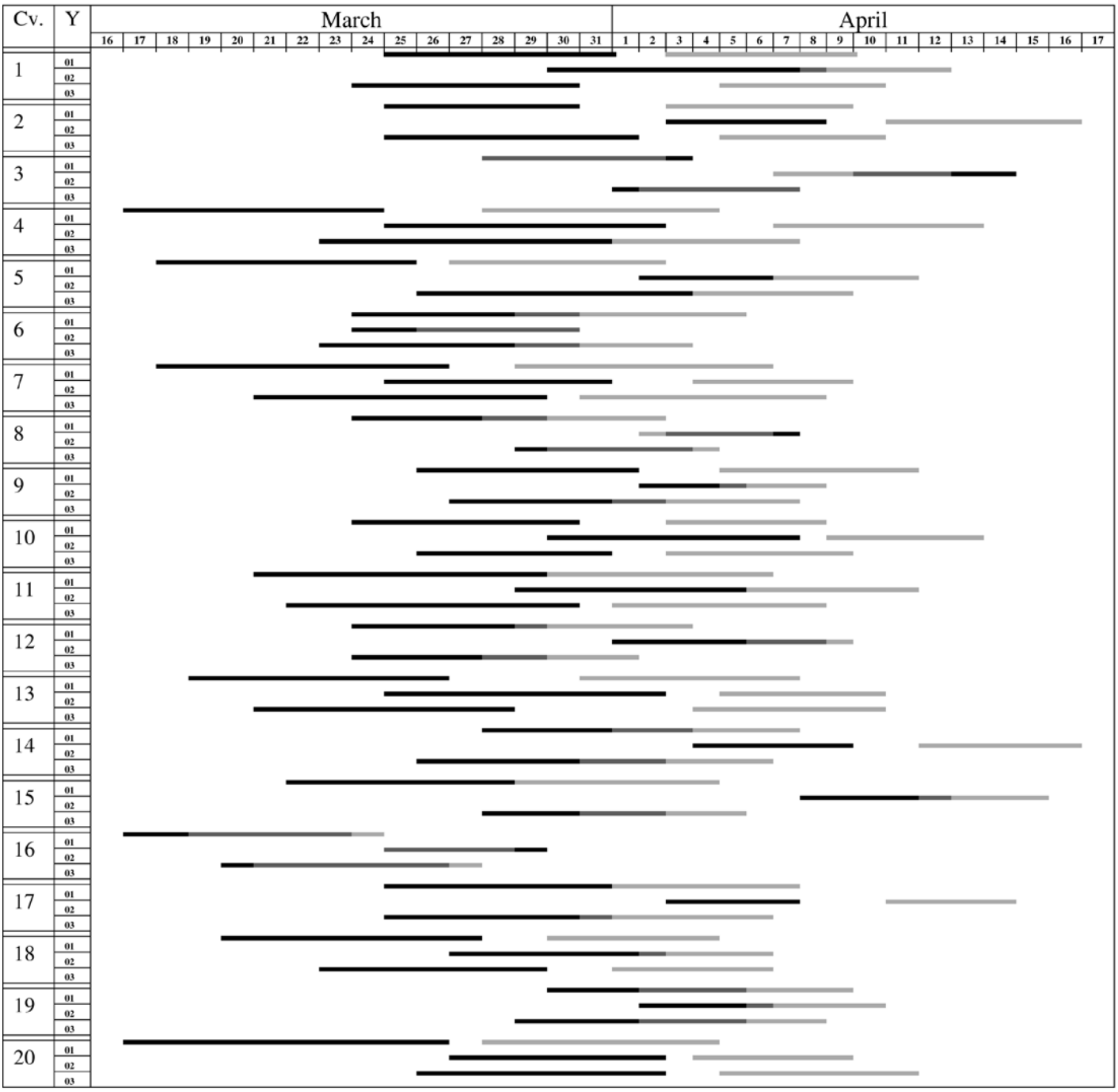

Fig. 2 - Duration of pollen shedding and stigma receptivity in different walnut cultivars/selections. Cv= Cultivar; Y= Year; 01= 2006; 02= 2007; 03= 2008.

1	ACO 38853	5	Plant No. 10	9	Rattan Akhrot	13	Inder Akhrot	17	Plant No. 46
2	Blackmore	6	Netar Akhrot	10	Lake English	14	Plant No. 32	18	Plant No. 47
3	Gobind	7	Roopa Akhrot	11	Kandaghat Selection	15	Xenia	19	Solding Selection
4	Hartley	8	KX Giant	12	Payne	16	Plant No. 45	20	Luxmi Akhrot

Duration of pollen shedding
Overlapping of pollen shedding and stigma receptivity
Duration of stigma receptivity

Table 1 - Nature and degree of dichogamy in different walnut cultivars/selections

Cultivar/selection	First year		Second year		Third year	
	Nature	Degree	Nature	Degree	Nature	Degree
ACO 38853	Protandrous	100	Protandrous	100	Protandrous	100
Blackmore	Protandrous	100	Protandrous	100	Protandrous	100
Gobind	Homogamous	14.28	Protogynous	50	Homogamous	0
Hartley	Protandrous	100	Protandrous	100	Protandrous	100
Plant No. 10	Protandrous	100	Protandrous	83.33	Protandrous	83.33
Netar Akhrot	Protandrous	62.50	Slightly protandry	33.33	Protandrous	57.14
Roopa Akhrot	Protandrous	100	Protandrous	100	Protandrous	100
KX Giant	Slightly protandry	33.33	Homogamous	0	Homogamous	14.28
Rattan Akhrot	Protandrous	100	Protandrous	60	Protandrous	57.14
Lake English	Protandrous	100	Protandrous	100	Protandrous	100
Kandaghat Selection	Protandrous	71.43	Protandrous	100	Protandrous	100
Payne	Protandrous	80	Protandrous	60	Protandrous	50
Inder Akhrot	Protandrous	100	Protandrous	100	Protandrous	100
Plant No. 32	Slightly protandry	28.57	Protandrous	100	Protandrous	42.86
Xenia	Protandrous	83.33	Slightly protandry	33.33	Protandrous	50
Plant No. 45	Slightly protandry	16.67	Homogamous	0	Slightly protandry	14.28
Plant No. 46	Protandrous	66.67	Protandrous	100	Protandrous	71.42
Plant No. 47	Protandrous	100	Protandrous	100	Protandrous	100
Solding Selection	Protandrous	42.86	Protandrous	60	Protandrous	42.86
Luxmi Akhrot	Protandrous	100	Protandrous	100	Protandrous	100

20 French cultivars 16 protandrous, three protogynous and one homogamous. Among 100 cultivars studied by Yadrov (1982) the majority was protandrous (approximately 60%), while approximately 30% were protogynous and only 10 % were homogamous. Working on 10 cultivars of French and American origin Aleta and Ninot (1987) identified six absolutely protandrous cultivars, one protogynous and three partly homogamous. Korac *et al*. (1989) found among 14 cultivars, 11 protandrous, two protogynous and one partly homogamous. The occurrence of heterodichogamy in Persian walnut (i.e. protandry, protogyny and homogamy) as revealed here, is reported also by several other workers (Cheng, 1978; Radicati, *et al.,* 1983; Cerovic *et al.*, 1995).

The present investigation on the nature of dichogamy is primarily based upon the overlap between pollen shedding and stigma receptivity and not on the conventional method of classifying varieties on the basis of time of emergence of male and female flowers. The degree and nature of dichogamy is a varietal character, but it is also greatly affected by tree age, climate and geographic location (Wood, 1932).

Thus it is concluded that dichogamy is genotype-specific as shown from the considerable variation observed in the 20 cultivars/selections studied. To achieve optimum fruit set and consequent yield, near homogamous types ('Gobind' or 'KX Giant') may be planted in single cultivar walnut orchards, or a mixture of cultivars can be interplanted to allow sufficient overlap between pollen shedding and stigma receptivity. On the basis of the present study on protandrous-protogynous dimorphism, the mentioned possible pollinators in Table 2 are suggested as suitable cultivars/ selections for growing in north-western India.

References

AKCA Y., SEN S.M., 1997 - *The relationship between dichogamy and yield-nut characteristics in* Juglans regia L. - Acta Horticulturae, 442: 215-216.

ALETA N., NINOT A., 1987 - *El Nogal. Un cultivo tradicional con futuro*. - Fruticultura professional, 11: 55-59.

BAUCKMANN M., 1974 - *The length of male flowers (catkins) on grafted walnut trees*. - Mitt. Rebe Wein, Obstbau Freuchterwert, 24: 463-466.

CEROVIC S., KORAC M., TODOROVIC J.N., 1995 - *Dichogamy in walnut (*Juglans regia L.*)*. - Jugoslovensko Vocarstvo, 29(3/4): 21-25.

CHENG W.C., 1978 - Juglans Regia L. - The Editorial Commission of Chinese Flora of Trees. The planting technology of the main forest trees in China, pp. 1342.

FORDE H.I., 1977 - *Walnuts*, pp. 439-455. - In: JANICK J. and J.N. MOORE (eds.). *Advances in fruit breeding*. Purdue University Press, West Lafayette Ind., USA.

GERMAIN E., JALINAT J., MARCHOU M., 1981 - *Divers aspects de la biologie florale de noyer*, pp. 13-27. - In: BERGOUGNOUX F., and P. GROSPIERRE(eds.) *Le Noyer*. INVUFLEC, Paris France.

GERMAIN E., JALINAT J., LEGLISE P., MASSERON A., TRONEL C., CHARTIER A., 1983 a - *Le noyer, resultants de 20 ans experimentation*. - Arb. Fruit., 356: 55-60.

Table 2 - Suitable pollinators for different walnut cultivars/selections

Main cultivars/selections	Suitable pollinators
ACO 38853	Plant No. 32
Blackmore	Gobind, Xenia
Gobind	Xenia, Plant No. 32
Hartley	Gobind, Xenia, Plant No. 32
Plant No. 10	Gobind, Xenia, Plant No. 32
Netar Akhrot	Roopa Akhrot, Inder Akhrot, Plant No. 45, Lake English
Roopa Akhrot	KX Giant, Plant No. 32, Plant No. 46
KX Giant	Kandaghat Selection, Plant No. 10
Rattan Akhrot	Plant No. 32, Plant No. 46
Kandaghat Selection	Plant No. 32, Xenia
Payne	Plant No. 32, Xenia
Inder Akhrot	Plant No. 32, KX Giant, Solding Selection
Plant No. 32	Gobind
Xenia	Gobind
Plant No. 45	Roopa Akhrot, Netar Akhrot
Plant No. 46	Gobind, Xenia
Plant No. 47	Solding Selection, Gobind, ACO 38853
Solding Selection	Plant No. 32, KX Giant
Luxmi Akhrot	Plant No. 32, Solding Selection, KX Giant, ACO 38853

GLEESON S.K., 1982 - *Heterodichogamy in walnuts. Inheritance and stable ratios*. - Evolution, 36(5): 892-902.

KORAC M., CEROVIC S., MITROVIAC M., KUZMANOVSKI I., JOVANEEVIAC D., SOLAR A., 1989- *Walnut production, population variability and breeding results achieved in Yugoslavia*. First Int. Symp. on Walnut Production, Budapest, Hungary, 25-29 Sept., pp. 9.

LUZA J.G., POLITO V.S., 1988 - *Microsporogenesis and anther differentiation in* Juglans regia L.*; a developmental basis for heterodichogamy in walnut*. - Bot. Gaz., 149(1): 30-36.

MAJACKAJA A.D., 1969 - *Dichogamy and fruiting in walnuts*. - Lesn. Hoz., 2: 32-35.

MANNING W.E., 1938 - *The morphology of the flowers of Juglandaceae. I. The inflorescence*. - American Journal of Botany, 25: 407-419.

McDANIEL J.C., 1957 - *The pollination of Juglandaceae varieties – Illinois observations and review of earlier studies*. - Nut Growers Assn. Annual Rep., 48: 89-93.

McGRANAHAN G.H., LESLIE C., 1991 - *Walnuts (*Juglans*)*, pp. 907-951. - In: BALLINGTON J.R., and J.N. MOORE(eds.) *Genetic resources of temperate fruit and nut crops*. ISHS Secretariat, The Netherlands, Vol. II, pp. 980.

RADICATI L., ME G., SACERDOTE S., VALLANIA R., 1983 - *Prime valutazioni di cultivars di noci Americana e francesi per le zone Montana*. - Frutticoltura, 45(3-4): 19-23.

SOLAR S., STAMPER F., SMOLE J., 1997 - *The degree of heterodichogamy of some walnut cultivars (*Juglans regia *L.) in Slovenia*. - Acta Horticulturae, 442: 217-224.

WOOD M.N., 1932 - *Dichogamy- An important factor affecting production in the Persian walnut*. - Proceedings of American Society for Horticultural Science, 34: 160-164.

YADROV, A.A. 1982. *Dichogamy and fruit production in walnut*. - Byulleten Gosudarstvennogo Nikitskogo Botanicheskogo Sada, 49: 68-72.