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Ideotype concept in black pepper (*Piper nigrum* L.)

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Abstract

An attempt has been made to describe the crop ideotype characteristics for black pepper (*Piper nigrum*). It is proposed that the black pepper ideotype should have acute branch angles (45^0) at the top and more wider branch angles at the bottom (60^0). The fruiting branches should be well spread from top to bottom of the canopy. To harvest maximum light especially by the bottom canopy, the leaf angle should be more at the bottom ($130\text{-}140^0$) compared to the top ($100\text{-}110^0$). It is desirable that within a branch, the bottom leaves have lengthier petioles than the top leaves. The vine should have a high photosynthetic rate (minimum of 3.0–3.5 µ moles), more than 90% bisexual flowers with >95% self pollination, increased spike length (≥12 cm) and more number of berries spike^{-1} (≥70). Fruit set should be ≥80% and should yield at least 2.5–3.0 kg dry berries vine^{-1}. Among the cultivars/varieties studied, Panniyur 1 was found to possess more number of traits for the proposed ideotype compared to other cultivars/varieties.

Keywords: black pepper, ideotype, *Piper nigrum.*

Introduction

In the simplest sense, the term ideotype means idea-type, or an idealized envisioned appearance that is desired. The term has been co-opted by plant breeders to describe the idealized appearance of a plant variety (http://en.wikipedia.org/wiki/Ideotype). Plant breeders have attempted to enhance the yield of crops by making selection for individual traits since the beginning of plant breeding. This approach has been broadened to encompass the breeding of model plants or ideotypes. An ideotype is a hypothetical plant described in terms of traits that are thought to enhance the genetic yield potential. Ideotype breeding is defined as a method of breeding to enhance the genetic yield potential of crops based on modifying individual traits where the breeding goal (phenotype) for each trait is specified (Rasmusson 1987).

The goal of ideotype breeding is to define theoretically the most efficient plant type for a particular crop and environment and breed towards the goal. More specifically, a crop ideotype is a plant model that is expected to yield more quantity/quality of oil, grain or other useful products in a particular environment. Hence the development of an ideotype has to take into account G x E interaction also. Depending upon the crop, physiological traits and the range of environment, the G x E interaction can be very large to practically non-existant. Hence, understanding of physiological processes is very much necessary for development of an ideotype (Fageria *et al*. 2006).

Black pepper (*Piper nigrum* L.) (Piperaceae) is cultivated for its matured dried fruits which is the most widely used spice in the world. The Malabar coast of India is involved in the cultivation and trade of black pepper since time immemorial from where, it was taken to Indonesia, Malaysia and then to other countries. Black pepper has originated in the western ghats of India, which is a rich source of biodiversity. The extent of variability existing in black pepper in India is also very large which has been domesticated leading to a large number of genotypes with widely varying productivity levels. However, presence of senile unproductive gardens, homestead system of cultivation and occurrence of pests and diseases contribute to low productivity of black pepper in India (Nybe *et al*. 2008). Parthasarathy *et al.* (2008) opined that the productivity in India in terms of the yield vine^{-1} is comparable to any other black pepper producing country in the world. They reported that studies carried out by the Centre for Development Studies indicated that the average population of vines ha^{-1} is around 300 with only two thirds of the vines in bearing condition but the production system in other countries except that of Sri Lanka (and to a lesser extent in Indonesia) is generally monocrop with population ranging from 1800 to 2200 ha^{-1}. Hence, the per vine productivity in these conditions will be same as that of India. As black pepper is a perennial climber and has indeterminate growth habit, it is not easy to define a crop ideotype for black pepper.

Climate and soil

Black pepper is a crop of hot humid tropics and its characteristic climatic requirements are, high rainfall, uniform temperature and high relative humidity. Well distributed rainfall ranging from 1000 to 3000 mm year^{-1} is required for its proper growth and development. The optimum temperature for its growth is around 20-30^0 C. In addition, drainage status and moisture holding capacity of the soil are also important. Long spells of dry weather are always harmful. Hence, an ideal variety should be able to yield better under limited moisture availability and should be responsive to irrigation, producing optimum yields when irrigation is given during critical stages.

Support (Standard)

The black pepper vine requires a support for its establishment. Both living and non-living supports (standards) are used to establish black pepper. An ideal living support should be straight growing and should have a tap root system that does not compete with black pepper for water, nutrients, and solar radiation; slender, but strong trunk with a rough surface; ability to withstand regular pruning and pollarding, and have economic value after the life span of the crop (Sivaraman *et al*. 1999). Use of ideal support trees plays a significant role in growth and yield of black pepper. Studies conducted at Kerala Agricultural University (Manjusha 2007) have shown that coconut, followed by jack and ailanthus, are best supports in terms of growth and yield of black pepper. Support trees propagated through cuttings generally showed competition with black pepper root system. Some of the common living supports are, *Erythrina indica*, *E. lithosperma, Garuga pinnata*, *Gliricidia sepium, G. maculata* and *Ailanthus malabarica*. *Grevillea robusta* is the best support tree for higher altitudes (Korikanthimath & Ankegowda 1999). Raising black pepper on live support is less expensive and increases productivity on a long term basis as compared to non-living supports (Azmil & Uau 1993; Varughese & Ghawas 1993; Wong & Paulus 1993). On forest tree supports, black pepper can grow to a height of more than 20 m. This results in accumulation of more dry matter and hence more berry yield.

Pruning of supports

Pruning of live supports before flowering enhances the yield of black pepper (Mathai & Sastry 1988). After establishment, periodical pruning is important to allow sufficient light penetration to the plant canopy (shade regulation). Support height may be restricted to facilitate harvest. Kato & Albuquerque (1980) found that 2.5 m height was more beneficial than 1.5 m. However, it is common to raise black pepper on coconut and arecanut plants which are more than 5 m in height. In Sri Lanka, *Gliricidia* sp. which provides abundant shade, is the most common support tree (Gunaratne & Heenkenda 2004).

But as the height increases, spraying of plant protection chemicals and also harvesting will become more difficult. As the black pepper

Table 1. Cultivation details of black pepper in major countries

Country	Area of cultivation	Soil	Variety / Cultivar	Support	Yield (kg ha^{-1})
Vietnam	Central Highlands, South East (Ba Ria Province) Vietnam, Quang Tri (North Central Highlands), Phu Quoc Island	Fertile basalt	Local cultivars, Cambodian varieties, Indonesian varieties (Lada Belangtoeng), Indian varieties (An Do)	Concrete post, brick support, dead wood support, live support	1410
Indonesia	Lampung, Bangka, South Sumatra, Kalimantan, Sulawesi	Brown latosol	Kerinci, Belantung, Jambi, Bengkayang, Lampung Duan Lebar	Live support (small holders in Lampung), dead support (in Bangka, East and West Kalimantan)	799
Malaysia	Kuching, Samarahan, Sri Aman, Sarikei and Sibu Divisions in Sarawak	Reddish brown sandy clay soil	Kuching, Djambi, Bangka, Belantung, Semongok Perak, Semongok Emas	Dead wood support	1642
Sri Lanka	Provinces of Central, North Western, Sabaragamuwa, Uva, Western, Southern	Well drained, loam soils rich in organic matter	Local cultivars, Panniyur 1, Kuching, PNMI	Live support	579
Brazil	States of Para, Espirito Santao, Bahia, Amazonas	Yellow and red latosols, basalt	Cingapura (Kuching), Bragantina (ecotype of Panniyur 1 hybrid), Guajarina (ecotype of Arkulam munda)	Dead post	2634
India	Kerala, Karnataka, Tamil Nadu	Red laterite	Karimunda, Kottanadan, Narayakodi, Aimpiriyan, Kuthiravally, Balancotta, Kalluvally, Sreekara, Subhakara, Panchami, Pournami, Panniyur 1 to 7	Live support: *Glyricidia* sp., *Erythrina* sp., *Garuga* sp., *Grevellia* sp.	237

Source: Parthasarathy *et al.* (2007)

vine climbs and grows on the support tree, an ideal support tree should be growing straight, should not have any branches up to 3-4 m height, should preferably have acute branch angle at the top and a more wider branches at the bottom with narrow leaves to allow more light interception by the canopy. Under intensive cultivation, pruning of black pepper may be practiced to ensure production of three shoots within 4-6 months of planting and to induce the development of lateral shoots (Pillai 1977; Kurian & Nair 1988; Azmil & Yau 1993).

Under monocrop culture, black pepper is planted at a spacing of 2.5 m × 2.5 m. Kurien *et al*. (1994) observed the highest competition between living supports and black pepper at closer spacing of 2.0 m × 2.0 m. In India, Madagascar, Lampong and Indonesia, live trees are used at wider spacing but yields are decreased (George 1981). *Erythrina* sp. and *Gliricidia* sp. are commonly used in Indonesia as living supports with planting distances of 2.0 m × 2.0 m or 2.5 m × 2.5 m (Zaubin & Manohara 2004). Details of cultivation in major black pepper countries is provided in Table 1.

Morphological characters

Plant height and branching pattern

Black pepper is a perennial, glabrous woody climber, 10 m or more in height. Under ideal situation when the height is restricted, the mature vine has a bushy columnar appearance and is about 4.0 m in height and 1.5 m in diameter (Purseglove *et al*. 1981). The vines, as they grow, exhibit dimorphic branching pattern consisting of monopodial, orthotropic branches and sympodial, laterally growing plagiotropic fruiting branches. The main orthotropic shoot has indefinite growth and produces lateral fruiting branches from the leaf axils. Clinging roots are present on each node of orthotropic shoots which help the plant to climb over the support trees and these can develop into normal underground roots when they come in contact with soil or when stem cuttings are planted (Parthasarathy *et al.* 2007).

Leaf length and width

Leaf characters form a major feature for cultivar identification in black pepper. The leaf size and shape on the emerging orthotropic shoots and runners differ from normal leaves found in lateral fruiting branches. Leaf size in varieties/cultivars varies from 8 to 20 cm or more in length and 4 to 12 cm or more in breadth (Purseglove *et al*. 1981; Ravindran *et al*. 2000a). Leaf length and width were lowest in Sreekara (10.0 and 6.7 cm) and highest in HP 1411 (12.0 and 9.7 cm).

Petiole length

The leaf petiole length is higher in runner shoots compared to lateral shoots. The average petiole length ranges from 4.5 cm (IISR Girimunda) to 5.6 cm (HP 1411) in runner leaves while it is 1.2 cm (Sreekara and Subhakara) to 1.9 cm (IISR Girimunda) in lateral leaves. To harvest maximum light, varieties with lower leaf petiole length at the top and increased petiole length at the bottom both in runner as well as lateral branches is ideal (Fig. 1).

Leaf angle

The leaf angle of the lateral leaves also varies among the cultivars/varieties. Highest leaf angle of 135-140^0 was noticed in OPKM and IISR Girimunda while the lowest (115^0) was recorded in HP 1411. The leaf angle should be more at the bottom compared to top which helps in filtering of more light to the bottom canopy (Fig. 1).

Stem

Shoots of black pepper are dimorphic. Orthotropic vegetative climbing shoots give the frame work of the plant and become stout, 4-6 cm diameter at the base and woody with a thick flake-like bark. Internodes are 5-12 cm long with a leaf at each swollen node, and an axillary bud which can grow out to a plagiotropic fruiting branch and climbing roots. Lateral fruiting branches have no roots (Purseglove *et al.* 1981).

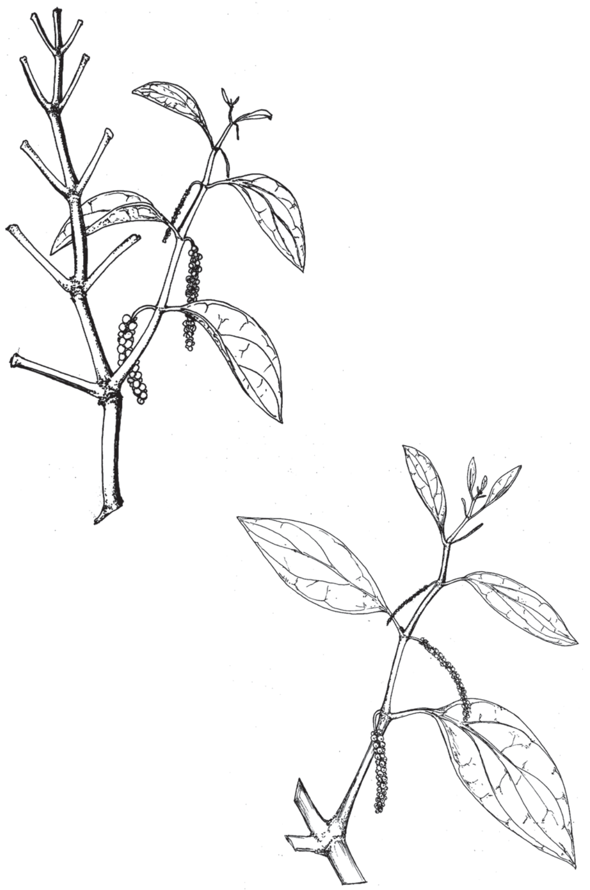

Fig. 1. Ideal branch angle (top), petiole length and leaf angle with a subtending spike in each leaf (bottom)

Fruiting branches

The vine should have rapid initial growth and produce lateral branches in the first year of growth itself. The lateral branches should emerge from the bottom portion of the vine also. The height of the plant can be restricted to 20 feet by pruning. The vine should be responsive to pruning and it should lead to increased lateral branches. The branch angles should be broader at the bottom compared to those at the top to harvest more light by the bottom canopy. Healthy black pepper vines which received summer irrigation during second fortnight of March to second fortnight of May at fortnightly intervals, had on an average, 18 to 22 lateral branches and produced 1.2 to 1.3 kg fresh berries per m^2 of the canopy (unpublished). The vine should have a minimum of 18-20 laterals per m^2 of the canopy.

Roots and root spread

The vine has 10-20 main adventitious roots from the base of the mature stem which penetrate to a depth of 1-2 m and an extensive mass of surface feeding roots which spread to a depth of up to 60 cm. The lateral spread of roots is mostly up to 60 cm from the base of the stem. To tolerate abiotic and biotic stresses, the variety should have a thick mass of roots with very good root proliferation capacity and should extend its roots down to 2 m and below to extract moisture under drought conditions.

Details of ideal morphological characters for black pepper ideotype is given in Table 2.

Table 2. Ideal morphological characters for black pepper ideotype

Vine height	<20 ft
No. of laterals per m^2	18-22 (Ankegowda *et al*., unpublished) (eg. Panniyur 1)
No. of leaves per m^2	180-200 (Ankegowda *et al*., unpublished) (eg. Panniyur 1)
Leaf length	10-12 cm (unpublished) (eg. Subhakara, Panniyur 1, OPKM, HP 780, HP 1411, Kalluvally, Narayakodi, Cheriyakaniakadan)
Leaf width	7-8 cm (unpublished) (eg. Subhakara, Panniyur 1, OPKM, HP 780, HP 1411, Kalluvally, Narayakodi, Cheriyakaniakadan)
Petiole length	1.2-1.5 cm at the top, 1.8-2.0 cm at the bottom ie., petioles of bottom leaves should be at least 0.5 cm lengthier than those of top leaves (unpublished) (eg. Sreekara, Subhakara, IISR Thevam, HP 1411)
Leaf angle	$110\text{-}120^0$ at the top, $130\text{-}140^0$ at the bottom (unpublished) (eg. IISR Thevam, HP 1411)
No. of roots and root spread	>15 adventitious roots; profuse root proliferation capacity; 1.5-2.0 m downward spread and 60 cm lateral spread (eg. Panniyur 1)

Physiological characters

Photosynthetic rate, stomatal conductance and transpiration rate

The photosynthetic rate in black pepper varies from 1 to 4 μ moles in different varieties. The stomatal conductance is in the range of 0.04 to 0.15 (unpublished). Those with better stomatal conductance had better photosynthetic rate but at the same time, transpiration rate was very high in these varieties. Hence, when water availability is limited, higher stomatal conductance with lower transpiration rate is preferred while under adequate water supply, higher stomatal conductance with higher transpiration rate is preferred to maximize the yield. Under severe water stress, stomatal conductance reaches very low levels (0.02 to 0.03) which results in very low photosynthetic rates of < 1.0 μ mole.

Leaf area, dry matter accumulation and translocation, and productivity

The upper part of the canopy with a relatively higher leaf area during the spike development period and higher photosynthetic rate promotes the growth and development of productive laterals and sustains relatively large number of spikes (Mathai 1983). For higher productivity in black pepper, exposure of higher leaf area to light, accumulation of high dry matter in the fruiting branches before spike initiation in June, higher carbon fixation capacity and higher translocation of photosynthates from leaves to the developing berries are very important. In productive varieties like Panniyur 1 and Karimunda, more than 50% of the radioactivity (uptake) was present in the adjacent spikes. The berries of these varieties also mobilized more photosynthates (Mathai 1983). It implies that, for obtaining better yields, the vine should produce sufficient lateral branches with optimum leaf area to harvest maximum light, have good carbon fixation ability and accumulate sufficient metabolites before spiking for further translocation to the developing berries.

Black pepper is normally grown under the shade of support trees. Higher light availability during pre-flowering (March to April) produced greater leaf area, more compact canopy structure, and higher metabolite production. This leads to increased production of lateral shoots during second flush, more flowers and spikes, greater number of berries vine^{-1}, and higher dry matter accumulation in berries (Mathai & Sastry 1988). A drastic reduction in leaf area of black pepper lateral after 60 days of spike initiation affects the yield severely due to limitation in the availability of current photosynthates (Mathai *et al*. 1988). Berry set percentage is significantly reduced if there is 75% leaf area reduction of subtending leaves (Krishnamurthy *et al*. 2000). Low yielding cultivars accumulated 80% of dry matter in laterals whereas high yielding cultivars accumulated only 50% in laterals and more dry matter in berries. Efficient dry matter partitioning in high yielding cultivars was strongly influenced by their total dry matter production (Mathai & Nair 1990). A productive vine should produce at least 2.0 kg dry berries during the 3rd year after planting and an average of 2.5-3.0 kg dry berries from 5th year onwards.

Light interception

Vine productivity decreases with decreasing light interception from top to bottom (Mathai & Chandy 1988). Shading of middle and lower canopies resulted in 50% yield reduction which is directly related to incident radiation (Ramadasan 1987). Illumination above 50,000 lux decreased carbon fixation in all cultivars except Panniyur 1, which also translocated higher percentage of photosynthates to the developing spikes during berry development, resulting in higher yield than in other cultivars.

Irrigation

The feeder roots of black pepper are distributed in the top 50-60 cm depth of soil and therefore sensitive to moisture stress (Raj 1978). Basin irrigation of vines at IW/CPE (irrigation water to cumlative pan evaporation) ratio of 0.25 from December to March increased the yield, while drip irrigation @ 7 l vine^{-1} day^{-1} from October to March produced maximum yield (Sivaraman *et al*. 1999). Irrigating black pepper vines once in a fortnight from March to May months @ 50 vine^{-1} can enhance black pepper yields substantially. The mean dry yield obtained was 6.80 kg vine^{-1} in irrigation treatment as against 3.25 kg vine^{-1} under rainfed condition.

Nutrition

Investigations on the mineral nutrition of Panniyur-1 in a laterite soil, poor in major nutrients indicated that application of 140g N, 55g P_2O_5 and 270g K_2O vine^{-1} year^{-1} resulted in significant increase in availability of N, P & K (Sivaraman *et al*. 1987). Sadanandan (1994) reported that the above dose in two equal splits is optimum and most economic in terms of yield response. Yield variability in relation to soil fertility in black pepper plantations was examined by Mathew *et al.* (1995). Near neutral soil pH, high organic matter content and high base saturation with Ca and Mg were found to influence nutrient uptake and productivity. The ideal black pepper variety should be fertilizer responsive and produce optimum yields with recommended dose of fertilizers.

Details of ideal physiological characters for black pepper ideotype are given in Table 3.

Yield attributing factors

Flower

Most of the black pepper cultivars are monoecious and have bisexual flowers. About 50-150 minute flowers are borne in the axils of ovate fleshy bracts. The cultivars vary from dominantly female to purely bisexual. Most of the improved varieties such as Panniyur 1, Panniyur 2, Panniyur 3, Panniyur 4, Sreekara, Subhakara and Panchami have >95% bisexual flowers while cultivars such as Cheriyakaniakadan (98.36%), Mundi (77.66%), Perambramunda (79.66%) and Perumkodi (73.05%) have dominantly female flowers (Ravindran *et al.* 2000b). High per cent of bisexual flowers are essential for good fruit set.

Pollination

Barber (1906) and Anandan (1924) attributed pollination of black pepper to splashing of rain. The latter reported that rain drops help scattering pollen grains to different directions, even to neighbouring vines. Lack of rain during the flowering period result in poor fruit set (Anandan 1924; Marinet 1955). Iljas (1960) reported geitonogamy in black pepper and found that free hanging spikes

Table 3. Ideal physiological characters for black pepper ideotype

Photosynthetic rate	Minimum of 3.0-3.5 μ moles (Krishnamurthy & Chempakam 2009) (eg. Panniyur 1, Acc. 1041, OPKM, HP 780, Acc. 4129)
Stomatal conductance	0.06-0.10 (Krishnamurthy & Chempakam 2009) (eg. Panniyur 1, Acc. 1041, OPKM, Acc. 4129)
Carbon fixation	>50 % of the fixed carbon should reach berries (Mathai 1983) (eg. Panniyur 1)
Light interception	Should intercept maximum light (eg. Panniyur 1)
Shade tolerance	Should produce minimum 70% yield at 200-300 μ moles light intensity (eg. Sreekara, Subhakara)
Drought tolerance	Should have dehydration tolerance and produce a minimum of 60% yield at 50% available moisture
Response to irrigation	Should produce the targeted yield with 40-50 l water vine^{-1} at fortnightly intervals during peak summer (March 2nd fortnight - May 2nd fortnight) (eg. Panniyur 1)
Response to applied fertilizers	Should produce the targeted yield with recommended dose of fertilizers (eg. Panniyur 1)

isolated inside polyethylene bags showed good fruit set. Selfing with occasional outcrossing is the predominant mode of pollination in cultivated bisexual black pepper (Sasikumar *et al*. 1992). The protogynous condition of black pepper affects fruit set.

Spike

Spike length varies among cultivars. The smallest spike is found in cv. Vokkalu (3.4 cm) and the longest spike in cv. Kuthiravally. The spike in black pepper may be straight or curved. The leaf-spike relationship showed that in majority of the cultivars, the spike length is almost the same as leaf length (Ravindaran *et al*. 2000a). The growing environment was found to affect spike length. For example, in Panniyur 1, the spike length was more under irrigated condition (13.0 cm) compared to those grown under rainfed condition (9.5 cm).

Berries spike^{-1}

Berries spike^{-1} also varies among cultivars. In general, cultivars with increased spike length will have more berries spike^{-1}. Pollination, water and nutrient availability and pest and disease attack during initial berry development period also influence berry number spike^{-1}. Panniyur 1 grown under irrigated condition has on an average 75-80 berries spike^{-1} compared to 30-40 berries spike^{-1} when grown under rainfed condition. Berries spike^{-1} is more prone to seasonal variation than spike length (Ibrahim *et al*. 1988). Ibrahim *et al*. (1985; 1987) reported spike yield and spike number in black pepper as important traits contributing for yield for which straight selection can be practiced for improvement. The quantitative traits, green berry yield vine^{-1}, spike number, spike length, and angle of insertion of the fruiting branch directly affect yield (Sujatha & Namboodiri 1995). Pillay *et al*. (1987) observed positive heterosis for spike length, number of developed fruits, bisexual flowers spike^{-1}, and yield.

Details of ideal yield and yield attributing characters for black pepper ideotype are given in Table 4.

Table 4. Yield and yield attributing characteristics for black pepper ideotype

Flowering	Should be synchronous and the flowers should be bisexual (>90%) (eg. Panchami, Panniyur 3, Panniyur 4, Sreekara, Subhakara, IISR Thevam)
Pollination	Self pollinating (>95%) (eg. Panniyur 1)
Fruiting	Should start during 2nd year and stabilize by 5th year
No. of spikes per m^2	150-200 (Ankegowda *et al*., unpublished) (eg. Panniyur 1)
Spike length	10-12 cm (Ankegowda *et al*., unpublished) (eg. Panniyur 1, Panniyur 2, Panniyur 3, Pournami, Panchami, PLD-2)
No. of berries spike^{-1}	70-80 (eg. Panniyur 1, Pournami, Panchami, IISR Malabar Excel, IISR Girimunda, IISR Shakthi)
Spike shedding	<5 %
Berry set percentage	Minimum of 80% (eg. Panniyur 1, Panniyur 3, IISR Thevam, IISR Girimunda, Panchami)
Test weight (100 berries, dry)	4.0-4.5 g (eg. Panniyur 1, Panchami)
Yield ha^{-1} (dry @ 500 vines ha^{-1}, mixed cropping)	1200-1500 kg (eg. Panniyur 1)
Yield vine^{-1} (average)	2.5-3.0 kg dry berries vine^{-1} from 5th year onwards (eg. Panniyur 1, Sreekara, Subhakara)

Crop protection

Foot rot

Phytophthora foot rot caused by *P. capcisi* is a major devastating disease of black pepper causing a crop loss of 25%-30% in Kerala and 44%-48% of vines in Karnataka (Mammootty *et al*. 2008). Crop loss of over 1000 t annually is reported at Kozhikode and Kannur districts in Kerala due to this disease (Devasahayam *et al*. 2008). The variety which has profuse root proliferation capacity especially during *Phytophthora* infestation is preferred, as vine death due to the disease is mainly due to complete destruction of root system. The ideal black pepper variety should be able to tolerate/resist this disease and produce good yield.

Anthracnose

Anthracnose disease caused by *Colletotrichum gloeosporiodes* is increasingly becoming serious at higher altitudes in Kerala and Karnataka. The disease when combined with predominance of female flowers, lack of pollination in rainfed areas, heavy shade and delayed emergence of spikes results in large scale spike shedding. The severity of the disease varies causing 1.93%–9.54% spike shedding. Highest incidence of the disease was recorded in Panniyur 1 followed by Balankotta. Vellanamban II showed no infection (Mammootty *et al*. 2008). The crop loss due to anthracnose was reported to be up to 67% in Kerala when the berries were infected at an early stage; the crop loss was higher when the spikes were affected (Devasahayam *et al*. 2008). Hence, to minimize anthracnose infection, the variety should be shade tolerant, early spiking, and should have more bisexual flowers.

Stunt disease

The stunt disease caused by viruses is characterized by vein clearing, scattered chlorotic flecks followed by chlorotic mottling along veins, leading to interveinal chlorosis and curling of leaves. In a few cultivars, vein banding, vein thickening and green island–like symptoms are also seen. The incidence of the disease is higher (45.4%) in Wayanad District in Kerala; in Karnataka the highest disease incidence (4.9%) was recorded in Kodagu District. The disease in more severe in cv. Karimunda and the yield loss due to stunt disease in infested vines varied from 16%-85% (Devasahayam *et al*. 2008).

Insect pests

The pollu beetle (*Longitarsus nigripennis* Mots.) is the most serious insect pest of black pepper and the pest infestation is higher (20%-32%) in plains and midlands (Premkumar & Nair 1984). Estimates of losses due to the pest range from 6% to 40%. The emerging insect pests which are becoming serious especially at higher altitudes include root mealybugs which infest the basal portion of the stem under the soil and also the roots (Devasahayam *et al.* 2008).

Nematodes

Nematodes are wide spread in all black pepper growing regions of the country. Yield losses ranging from 39% to 65% were recorded when black pepper vines were inoculated with *Radopholus similis* or *Meloidogyne incognita* alone or in combination under simulated field conditions (Eapen *et al*. 2008). Nematodes infest root system of the vine, thus affecting water and nutrient uptake and leading to slow wilt disease. In general, a variety with a very good root proliferation capacity is ideal in black pepper as *Phytophthora*, root mealybugs and nematodes, all extensively damage the roots resulting in vine death.

The limit for pest and disease incidence in black pepper ideotype is presented in Table 5.

Quality

The pungency (spiciness) of black pepper is mainly attributed to the presence of piperine. In popular black pepper cultivars, piperine concentration varied from 2.8% to 3.8% (Zachariah *et al*. 2005). Piperine content of 6.6% has been recorded in Panniyur 2 (Zachariah 2008). The aroma and flavour of black pepper is mainly contributed by the volatile oil which varies between 2%-5% in

Table 5. Limits for disease and pest tolerance for black pepper ideotype

Phytophthora incidence	Should not exceed 5%
Anthracnose incidence	Should not exceed 10%
Pollu beetle incidence	Should not exceed 5%
Radopholus similis incidence	Should not exceed 5%
Meloidogyne incognita incidence	Should not exceed 10%

the berries. Over 55 compounds have been identified from the volatile oil of black pepper. The major compounds identified were: α and β-pinene, sabinene, limonene, β-caryophyllene, myrcene, p-cymene and caryophyllene oxide (Gopalakrishnan *et al.* 1993; Menon *et al.* 2000; 2002; 2003; Menon & Padmakumari 2005). Oleoresins are commercially important because of the consistency in flavour, taste, antioxidant properties, increased shelf life and less storage space as it is a highly concentrated product (Zachariah 2008). As black pepper is traded mainly for its quality, the ideotype should have at least an average percentage of all the quality constituents along with high berry yield. Varieties with higher bulk density, higher percentage of bold berries and higher driage percentage are preferred (Table 6).

Conclusion

The black pepper ideotype should have acute branch angles (45^0) at the top and more wider branch angles at the bottom (60^0). The vine should have lateral branches from base to tip and 20-22 lateral branches per m^2 of the canopy. The leaf angle should be less at the top ($100-110^0$) compared to bottom ($130-140^0$) which may be helpful for the bottom leaves to harvest more light. Similarly, leaf petiole length should be less at top and more at the bottom. It should have higher radiation use efficiency, higher photosynthetic rate (>3 μ moles) and better translocation capabilities, with more than 90% bisexual flowers with >95% self pollination, increased spike length (≥12 cm) and number of berries spike^{-1} (≥70). Fruit setting should be ≥80%. Each lateral leaf should have at least one subtending spike and should yield at least a minimum of 2.5–3.0 kg dry berries vine^{-1} with a minimum of 5% of essential oil and piperine and 8% of oleoresin. The bulk density of berries should be a minimum of 500 g l^{-1} with a minimum of 30% driage. Though no single cultivated variety was found to possess all the ideal characters, Panniyur 1 has most of the characteristics of the proposed ideotype.

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Table 6. Minimum quality standards for black pepper ideotype

Essential oil	Minimum of 5% (Parthasarathy 2008) (eg. Sreekara, Subhakara)
Piperine	Minimum of 5% (Parthasarathy 2008) (eg. Sreekara, Panniyur 2)
Oleoresin	Minimum of 8% (Parthasarathy 2008) (eg. Sreekara, Subhakara, Panchami, IISR Shakthi, IISR Girimunda, IISR Thevam, Pournami, IISR Malabar Excel)
Bulk density	Minimum of 500 g litre^{-1} (Parthasarathy 2008)
Driage	Minimum of 33% (Parthasarathy 2008) (eg. Sreekara, Subhakara, Panchami, IISR Shakthi)

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