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Kala zeera (*Bunium persicum* Bioss.): a Kashmirian high value crop

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Abstract: Kala zeera is a high value, low volume, and under-exploited spice crop that grows in mountainous regions of Kashmir in the Himalayas. It has received very little attention in terms of development, standardization of production technology, and plant protection management practices. Sher-e Kashmir University of Agriculture Sciences and Technology (SKUAST-K) and other organizations have instituted programs for systematic improvement of Kala zeera. In this paper, we offer a synopsis of the latest work being done in promoting this high value crop, which would have a beneficial effect for the encouragement of economic activity in the Himalayas.

Key words: *Bunium persicun*, Apiaceae, spice

Kala zeera (*Bunium persicum* Bioss.): Kaşmir Himalaya bölgesi için pahalı bir baharat

Özet: Kala zeera Kaşmir Himalayalarında çok az sayıda bulunan fazla incelenmemiş bir baharat bitksidir. Varyete geliştirme, üretim teknolojilerinin satandardizasyonu ve bitki koruma uygulamaları açısından pek ilgilenilmemiş bir bitkidir. Kala zeera baharatının sistematik olarak geliştirilmesi için SKUAST-K ve else where, programı kullanılmıştır. Bu çalışmada bizim üniversite ve diğer yerlerde Himalaya dağlarında yaşayan insanlara ekonomik olarak büyük fayda sağlayacak baharatın değerini artırmak için yapılan çalışmalar özetlenmiştir.

Anahtar sözcükler: *Bunium persicun*, Apiaceae, baharat

Introduction

Kala zeera (*Bunium persicum* Bioss.) is a high value herbaceous spice widely used for culinary, flowering, perfumery and carminative purposes. It is known worldwide for its medicinal value and is known by different names (Table 1). It belongs to the family Umbellifereae (now called as Apiaceae). The family Apiaceae consists of 423 genera and 3000 species mostly aromatic herbs dispersed throughout the world especially in northern hemisphere (1). Besides, being a source of essential oils rich in terpenoids and phenylpropanoids, polyene and phototoxic furanocoumarins are typical of this family. Until recently, there was considerable confusion concerning Kala zeera, as it has been mistakenly referred to as *Carum bulbocastanum* or *Cuminum nigrum*. *B.*

Table 1. Names of Kala zeera in different languages .

Language	Name
Danish	*Sort kommen*
Dutch	*Zwarte komijin*
English	*Black cumin*
Esperanto	*Nigra kumino*
French	*Cumin noir*
German	*Schwarzer kraizkummel*
Hindi	*Kalazeera, shahi jeera*
Italian	*Cumino nero*
Japanese	*Burakku-kumin*
Kannada	*Shahijirige*
Kashmiri	*Zeur*
Lithuanian	*Persinis gumbakmynis*
Nepali	*Kalijira, Himali jira*
Persian	*Zireh-e-Irani, Zireh-e-Kuhi*
Punjabi	*Kala Jira*
Sanskrit	*Krishna jiira*
Spanish	*Comino negro*
Urdu	*Kalazira*

persicum is also sometimes confused with Black cumin or Roman coriander (*Nigella sativa*) belonging to the family of Ranunculaceae, which is also Mediterranean in origin.

Kala zeera might have originated in the area between Central Asia and Northern India. It is found growing naturally in alpine and sub-alpine habitats of northwestern Himalayas at an altitude of 1800-3500 m amsl. It generally grows in forests, grassy slopes, and to some extent in low alpine pastoral lands in the states of Himachal Pradesh, Uttranchal and Jammu, as well as Kashmir. The species has now been domesticated and developed for scientific production (2).

In Jammu and Kashmir, Kala zeera is confined to hilly traits of Gurez, Machill, Tangdar, Pulwama, Paddar, Karnah, Karewas of Budgam and Srinagar. As per the department of forest estimates for year 1996-97, Kala zeera occupied about 225 hectares of forestland producing about 29 t of seed spice with Baramulla District leading the table. Since the crop usually grows wild in scattered pockets, the yields are lower at 129 kg/ha (J&K) and 179 kg/ha (H.P.), as compared to 350-400 kg/ha in the case of caraway (*Carum caraway*). The low productivity is mainly due to poor crop management practices, inadequate planting density, high weed incidence, disease, insect damage, and lack of nutritional processing techniques (3). Moreover, due to the relentless collection of seeds by rural population, erosion has encroached on its ecotypes and the crop has become an endangered species.

Botanical description

Bunium persicum (2 N =14) is a member of Apiaceae (carrot family). The family consists of about 423 genera, mostly herbs, shrubs, trees and aromatics (4). The genus *Bunium* contains about 166 species, including *B. persicum* (Figure 1), *B. carum, B. bulbocastenum, B. copticum, B. flexuosum, B.elegans, B. cylendricum and B. chaerophyllocides* that are prevalent in Central Asia, Caucasus, Crimea, and Europe (5). The most distinctive feature of the Apiaceae is its inflorescence "umbel," which means "sunshade". It is a convex or flat-topped flower cluster in which all the pedicles arise from the same apex. The other distinctive feature is its fruit. *Shizocarp* consisting of two mericarps that are often attached to an entire or deeply forked central stalk (carpophore) with globular or elongated oil canals (vittae). The stem is often hollow in the internodal region with secretory canals containing ethereal oils and resins (6). The plant type of Kala zeera varies from dwarf (30 cm) to tall (80 cm) compact or spreading, moderately to highly branched, tuberous and perennial herb (7). The leaves are freely, pinnate (2-3), finely dissected and filiform. The flowers are small, white in color with readily symmetrical small sepals, petals and stamens

Figure 1. Kala zeera (*Bunium persicum* Bioss.).

(each five in number), and are present in compact umbels. The bracts are linear, sometimes divided, and bracteoles are absent with asymmetrical rays. The gynaecium is bicarpelate with inferior ovary with two styles fused at the base. The 1,000 seed weight is around 2 g. tubers of Kala Zeera are of hypocotyls or root origin.

Little information has been generated regarding cyto-morphological studies. The somatic chromosome number in *B. persicum, B. chaerophyllocides* and *B. cylendricum* has been reported to be 2N = 14, 12, and 20 respectively (8). We also carried out such studies in *B. persicum* and found 2N=14. A study on male meiosis in PMC's and mitosis in root meristematic cells were done on various ecotypes. Meiotic divisions were regular with normal disjunction of chromosomes. Pollen fertility was above 95% in all cases. The diploid nature of Kala zeera with 14 chromosomes has also been reported (2,9).

Systematics of Kala zeera

Kingdom	=	Planteae
Division	=	Magnoliopsida
Order	=	Apiales
Family	=	Apiaceae
Genus	=	*Bunium*
Species	=	*persicum*

Chemical composition

The Kala zeera seeds are used by indigenous as stimulants, carminatives, and are useful in diarrhea and dyspepsia (10). The extracts of *B. persicum* have hypoglycemic activity and can prevent diabetes and obesity (11). It is also used for culinary purposes and for flavoring food and beverages. The aroma of fruits is earthy and heavy, but on frying or cooking, it changes to nutty. The ripe zeera seeds contain an essential oil (5-14%) rich in monoterpene aldehyde. The main components are cumin aldehyde, p-mentha-1, 3-dien-7-al and p-mentha-1,4-dien-7-al (7). Comparative analysis of major volatiles from wild and cultivated sources of zeera seeds (12) revealed that the flavor of Kala zeera is mainly due to γ-terpinene and p-cymene. The oil from a cultivated source was more superior to that from wild sources.

The seeds of cultivated origin contained cummaldehyde (27-34%) followed by p-mentha-1,3-dien-7-al and p-mentha-1,4-dien-7-al (29-36%), whereas the seeds from the wild mainly contained γ-terpene (25-42%) and p-cymene (24-27%) and less aldehydes. They also reported that the straw of Kala zeera also contains 1-20 per cent oil that resembled the oil from seeds. Jassbi et al. (13) analyzed essential oils from *B. elegans* and *B. caroides* and found that their essential oils mainly contained sesquiterpene hydrocarbons such as germacrene-d and E-caryophyllene amounting to 24.1%, 38% for *B. elegans,* 22.1% and 26.6% for *B. caroides* respectively. *B. elegans* oil also contained traces of monoterpenes, while *B. caroides* oil contained various phenylpropenoids such as asaricin (7.5%) and dillapiolle (10.2%) as important constituents. Similarly, Shiva et al. (14) reported that the essential oil derived from *B. cylendricum* mainly consists of Myristin (43.1%), β-phellandrene (20%), β-pinene (15.6%) and α-pinene (10.7%).

The supercritical fluid extraction method for volatile components from *Bunium persicum* was used by (15) and found that a total of 16 compounds accounting for about 99.36%. Main components were 4-terpine (37.98%) followed by cumin aldehyde (11.48%), and α-methyle-benzenemethanol (25.55%), whereas, the rest was accounted for by components such as α-pinene, β-pinene, myrcene, α-terpinene, α-cymene, limonene, α-terpinolene, β-sinensal, β-selinene, Germacrene-B, and Dillapiole. The components, namely γ-terpinene, p-cymene and β-pinene, are thought to reduce the quality of the spice (16,17). The percentage of oil content recovered at 50%, 90% and complete seed set were 6.25%, 8.75% and 6.0% respectively (18). Therefore, it is suggested that for medicinal and culinary purposes, Kala zeera should be harvested at 90% seed set (19). The oil percentage is found to be highest in primary umbels followed by tertiary and secondary umbels. While as the p-cymene content is highest (36.33%) in primary umbels, γ-terpinene is highest (29.41%) in tertiary umbels (3). Both stalk and straw contained essential oil up to 2.0-2.8% and 0.7-0.8% respectively. Among various ecotypes of Kashmir valley, the collection from Gurez had the highest oil content (8.5%), followed by Drass/Kargil (7.5%), Padder (6.5%), Chare-Sharief (6.0%), Harwan (4.5%), and Khrew (3.5%).

Constraints in realizing higher yields

Even though Kala zeera is a high value crop, it is relatively unexploited in terms of breeding efforts aimed at seeking higher yields through genetic manipulations besides standardization of agronomic management practices. However, there are obvious constraints that have limited the genetic improvement of this valuable spice crop, especially in the Jammu and Kashmir states.

1) Lack of distinct and high yielding cultivars is one of the major constraints in harnessing the full economic potential. However, characterization of germplasm resources and selection for superior types is hampered by the long duration of the seed to seed cycle in this crop, wherein the crop comes to first bearing after 3 years of planting of seeds.
2) Low germination percentage of seeds is another major bottleneck. This is especially true in case of seeds procured from rural populace as they harvest the crop even when it is not fully mature. The lower germination of seeds is probably due to the fact that a large proportion of seeds arising from later formed umbels lack fully grown embryos and thereby fail to germinate.
3) Lack of standard agronomic management practices to harness the genetic yields potential of different ecotypes. Since, the crop has been under natural production system for quite a long time without any systematic management practice, the sustainability of its yields has been jeopardised and as such yields have remained static around 120 kg/ha in the state of Jammu and Kashmir.
4) Incidence of disease like leaf blight and umbel blight (*Alternaria alternata*), tuber rot (*Fusarium solani*) and powdery mildew significantly influence its yield potential. It has been reported that disease incidence causes upto 38% reduction in yield in Kala zeera. Blight disease was found to attack the crop first immediately after the emergence of sprout whereas powdery mildew appeared at flower bud and developing grain stages. Tuber rot shows the highest incidence (35.2%) followed by blight (19.87%) whereas powder mildew was mild (5.4%). In Kashmir, highest incidence of these diseases has been recorded in Baramulla district and the incidence increases with advancement of phonological stages. Similarly various insect pests such as pod borers, cabbage similooper, hairy caterpillars, aphids, black bean bugs, white grubs, thrips etc. infested the crop at flowering and seed developmental stages. Out of these, the cabbage semilooper (*Thysanoplusia orichalcea*) has been categorised as major pest of economic importance in dry temperate areas (20). Nematodes are also potential pests of kala zeera. Our studies revealed that nematode population ranged from 542.4 to 1056.5 per 250 mL of soil. These nematodes predispose plants to fungal, bacterial and viral diseases.
5) Low production and uncertain quality
6) Lack of trade standards
7) Ruthless collection of seeds leading to the erosion of genetic diversity of this crop.

Strategies for realizing higher yields in Kala zeera

Collection and characterization of germplasm

Collection and characterization of germplasm resources representing the available genetic variability is a basic requirement for initiating a crop improvement program. Plant breeding uses a selection process to derive a superior performing lines/cultivars that could meet the requirement of intensive agriculture for seeking higher productivity. The Kashmir valley possess rich germplasm repository of Kala zeera. With the initiation a crop improvement program, a large-scale collection and characterization of Kala zeera germplasm was taken up in the Kashmir valley. Under the NATP sub-project on Kala zeera, target surveys were conducted to pool the diverse ecotypes of this crop across diverse locations. The hilly regions of the valley were surveyed to identify the hot spots of diversity and the areas where the natural population of Kala zeera grew under natural conditions. These populations were regularly observed at flowering and fruit maturity stages for recording various morphological and yield attributing traits. Exploratory surveys were conducted in Jammu, Kashmir, and Himachal Pradesh, where 105 collections were made and evaluated for existence a genetic variability in respect of yield components and essential oil content (3).

Out of the 105, 19 germplasm lines (9 from Jammu and Kashmir, 10 from Himachal Pradesh) were identified as superior to the natural sample in respect of plant height, 100-seed weight, seed yield, and essential oil content. For yield traits and yield, SKUA-KZ-103 (yield potential of 432.27 kg/ha) recorded an increase of 200% over natural population whereas, for essential oil content, the collection from Shong area of Himachal Pradesh was the more superior. A high yielding variety identified (SKUA-BZ-86-01) is proposed for release under the name "Black perfume." It has a desirable yield and quality.

Various germplasm lines of Kala zeera from Himachal Pradesh and Kashmir valley were also characterized using morphological and RAPD markers (21). Using dandrogram, they were able to classify the lines into two clusters. Cluster-I consisted of lines from Gurez, Sangla and Khrew, while cluster-II included Kalpa and Harwan accessions.

Saroj Devi (22) has evaluated the germplasm of *B. persicum* from Kinnaur, Lahul, Spiti, Chamba, Shong, Kalpa and Kilmaur districts of Himachal Pradesh. They found a high degree of genetic variability for all the traits studied especially seeds/plant (Range : 553-1363.38). Heritability was high (up to 98%), except for umbel diameter. Genetic gain for yield component traits was also high (up to 62.97%). The results suggested that using appropriate breeding strategies, sizeable improvement can be realized in yield levels of Kala zeera using optimum selection indices. A positive correlation has been linked between the seed yield of Kala zeera with a number of primary and secondary umbels per plant, umblets/secondary umbel and tuber weight/plant (23). Similarly, Panwar and Badiyala (24) reported that grain yield in Kala zeera was strongly correlated with grains/umbel, grains/umblet, secondary branches/plant, umbels/plant, and umbel size. These traits could be used to improve the seed yield of Kala zeera. Mittal et al. (25) studied various morphological and yield traits in Kala zeera and found that seed yield was significantly correlated with all traits except seeds/primary, with secondary umbels with primary umbels/plant, secondary umbels/plant, and straw yield/plant being important traits affecting seed yield.

Similarly, at the Zeera Research Sub-Station, Gurez, germplasm lines from ten diverse locations of Kashmir valley were evaluated for various traits (Table 2 and 3). The clone from Chrar-e-Sharief exhibited superior yield performance (2.81 q/ha), seedling survival and germination percentage.

Standardization of agronomic management

In order to tame any wild crop and bring it into cultivation, it is imperative to standardize the package of practices to harness the genetic yield potential. Since, Kala zeera is a perennial crop, sequential availability of nutrients at active crop growth states is quite essential. A number of studies have been

Table 2. Morphological studies and growth habit of identified ecotypes of Kala zeera.

Location	District	Altitude (ft)	Active Vegetative growth phase	Time of harvesting	Plant height (cm)	Yield (q/ha)	Oil content (%)
Gurez	Baramulla	9500	1st week of May	Last week of July	65.85	1.95	8.5
Tilail	-do-	9800	-do-	-do-	69.26	1.90	-
Khadanyar	-do-	6500	2nd week of April	First week of July	55.23	1.85	-
Wasturwan Tral	Pulwama	7200	-do-	-do-	65.54	2.42	-
Harwan Dara	Srinagar	6500	1st week of April	Last week of June	68.26	2.75	4.5
Charisharif	Budgam	6155	-do-	-do-	70.20	2.81	6.0
Khrew	Sriangar	6600	2nd week of April	-do-	54.20	2.20	3.5
Drass	Leh	11,200	2nd week of May	Last week of July	55.27	1.90	7.5
Kargil	Kargil	10,800	2nd week of May	Last week of July	41.60	1.95	7.5
Padder	Doda	8500	2nd week of April-	1st week of July	46.26	1.85	6.5

Table 3. Germination and seedling characters of different eco-types of Kala zeera.

Seed lot	Days to germination	Germination percentage	Seedling survival (%)	Seedling height (cm) (1st year)	Days to withering
Charie-Sharief	190.40	55.20	94.71	7.50	45.00
Harwan	192.30	43.50	95.20	7.30	50.50
Khrew	195.50	42.30	82.00	6.93	41.25
Baramulla	200.50	41.00	88.14	6.92	43.20
Paddar	204.50	41.50	76.35	6.82	41.60
Drass	208.80	37.50	85.95	6.15	40.22

conducted to arrive at an optimum level of fertilizers and FYM for this valuable crop. Thappa et al. (12) first reported that Kala zeera responds well to cultural management practices and yields four times more than that the wild state. The response of Kala zeera yields to varying bulb size and planting density was studied by (23) who reported that large sized tubers had significant bearing on yield attributes, such as primary branches/plant, umbels/plant, grains/umblet, grains/umbel and grain yield, while plant height and secondary branches/plant were unaffected. The highest grain yield (377. 72 kg/ha) was obtained when tubers were planted at a depth of 10 cm.

FYM at the rate of 20 t/ha and NPK at the rate of 80: 18: 21 kg/ha resulted in the highest seed yield (426.9 kg/ha), besides improving NPK uptake and post harvest soil nutrient status in Himachal Pradesh (26). In Kashmir, FYM at the rate of 15 t/ha and NPK at the rate of 60: 30: 20 kg/ha resulted in a yield of 214 kg/ha showing an increase of 128.78% over control. At our station, we found that FYM at the rate of 20 t/ha and NPK at the rate of 80: 40: 20 gave seed yield of 187.32 kg/ha. The FYM P and K was used as single basal dose, while N was split in two equal doses and applied at vegetative and flowering stages. Chauhan *et al.* (27) has studied the effect of FYM and NPK on Kala zeera and observed that in case of morphological traits, such as plant height, tillers/plant, and umbel diameter, FYM at the rate of 20t/ha and NPK at the rate of 120:60:45 were the optimum doses. In case of yield traits, significant increase was observed up to 30 t/ha FYM and NPK at the rate of 120:60:45, even though the optimum dosage was 20 t/ha, FYM and NPK at the rate of 60:35:30 resulted in an insignificant increase in yield and yield components.

Optimum plant density and tuber weight are other important factors for enhancing seed yield in Kala zeera. The low yield in Kala zeera is also due to the fact that this crop is grown under a natural habitat in scattered pockets. Chauhan (28) has reported that 20 × 25 cm spacing was optimum with seed yields of 344 kg/ha. The seed yield was significantly affected by the size of the tuber; large sized tubers (5-8 g) gave higher yields than smaller tubers (1.5-3 g). Faravani (29) used various seed rates and found that 60 kg/ha produced bulbs of highest weight (1.98 g). In case of tubers, 200 tubers per square meter with row spacing of 25 cm gave the highest seed yield of 604.1 g (29). The optimum depth of sowing of tubers has been found to be 12.5 cm (23).

Studies carried out by the K.D. Research Station (SKUAST-K) revealed that both spacing and tuber weight had a significant affect on seed tuber weight and seed yield. The plant density of 0.25 million tubers/ha with tuber size of >3 g gave maximum seed yield (250 kg/ha), with planting geometry of 2 × 20 cm (30). At Zeera Research Station, we observed that tubers lifted after three years with a weight of 2-3.5 g are ideal for sowing in spaces of 25 × 25 cm. The tuber weight of >3 g gave a mean seed yield of 242.70 kg/ha, while plant density of 0.2 million tubers/ha (20 × 25 cm) gave a seed yield of 229.40 kg/ha. Four year-old tubers with a weight of 3.5-6.5 g gave highest seed yield (272.5 kg/ha). It is reported that seed yield is conditioned by age of bulbs and the three and four year old bulbs yielded 230 and 245 kg/ha, respectively (27). The planting geometry exerts its effect by affecting tuber weight, plant height, umbels/plant, and seed/umbel.

Disease and pest management

Cultural practices, solarization of soil, and sowing of garlic seeds between beds has a beneficial effect. Phenamiphose @ 500 ppm and carbosulfan @ 1,000 ppm can reduce the pest population during crop growth. Use of Phorate 10G at the time of land preparation cuts worm damage. Among the various fungicides, Myclobutanil 10WP (0.03%), Hexaconazole SE (0.03%) and Dodine 65WP (0.06%) were the most effective for controlling tuber rot with disease incidence of 2, 4, and 6%, respectively. Myclobutanil 10WP (0.03%) was also effective against leaf blight. Similar to nematodes, soil solarization during the summer before sowing has been found to be useful. Zinc Phosphide (5-6 g per 100 g of dough) can be applied using standard baiting strategies to control rodents. We found that sowing of garlic seeds on boundaries and as an inter-row crop were effective in repelling insects and rodents.

Enhancing seed germination

Dormancy is an important component of the lifecycle of most perennial crops in which the meristem activity is ceased and plant is rendered insensitive to growth promoting signals (31). The seasonal cycle of growth and dormancy involve various overlapping phases, such as active growth, onset of dormancy, maintenance of dormancy, release of dormancy, and onset of growth. Chilling treatments has long been thought to be a critical factor in the release of dormancy (32), but the exposure to low temperatures, in most cases, is long term.

Kala zeera seeds have inherently a lower seed germination percentage due to various factors and needs longer periods of chilling for germination. The poor germination results in larger seed rates and sub-optimal plant densities. Since the onset of embryo dormancy is associated with accumulation of growth inhibitors, breaking dormancy by shifting the hormonal balance has been the focus of research. Bonyanpour and Khii (33) analyzed various factors influencing seed germination in *B. persicum* and reported that stratification at 3-5 ^{o}C for 20 days resulted in seed germination, but the best germination occurred at 46 days. They further reported that the optimum temperature for seedling growth is 10-25 ^{o}C with seedling having 3-5 mm long radicles resulting in better crop establishment. Pouresmail and Sharifi (34), in addition to using stratification treatment at 4 ^{o}C for 4 weeks, used Kinetin or benzyladenine (10^{-5} mM), and found that the increased duration of stratification and benzyladanine enhanced seed germination in black zeera. Kaushal and Rana (35) used GA and IAA to study its affects on the percent of sprouting in Kala zeera and observed that exogenous application of GA_3 @ 500 ppm increased sprouting and affected plant height, branches/plant, and mericaprs/umbel. Plant growth regulators, such as KNO_3, PEG, Thiourea, GA_3, kinetin, and benzyladenine, in combination with stratification were used to optimize the seed germination of Kala zeera (36). They reported that among growth regulators benzyladenine (10^{-5} mM) alone gave the highest (68.7%) seed germination as well as (BA + GA_3 (10 mg/L) enhanced it to 82.8% and with BA + PEG (30 g/L) seed germination was 73.4%. However, the highest seed germination of 92% was achieved when BA was used along with stratification @ 4 ^{o}C for 4 weeks. With stratification alone, only 24.9% seeds germinated. The nitrogenous compounds, such as nitrite, nitrate, and thiourea, are known to promote seed germination by enhancing the activity of growth factors (e.g. GA_3, ethylene and cytokinins) (37). Similarly, osmotic agents, such as PEG, promote water imbibition thereby initiating germinating process (38). The stratification treatment (moist chilling) has been in use for quite some time as an inexpensive method of promoting seed germination via cold-stimulation of various enzyme systems (39). Although there are conflicting reports about the optimal duration of most chilling, 2-15 weeks stratification at 4 ^{o}C has been reported in many crops, with 8 weeks recording the highest germination.

Biotechnological interventions

One of the major constraints in commercializing *B. persicum* is its long juvenile period (3-4 years), which is affected by seasonal fluctuations. Therefore, large-scale production of micro-tubers as planting material is a much needed research focus that would open up opportunities for development of transgenics. Early attempts at somatic embryogenesis and organogenesis in *B. persicum* were conducted by (9), who were able to obtain callus from mericarps using MS medium (40) supplemented with 2, 4-D (2 mg/L) and kinetin (4 mg/L). The callus developed into numerous globular embryos on same the basal medium. Hypocotyl and cotyledons have been also used as explants (41) using B5 medium containing NAA (2 mg/L) and kinetin (2 mg/L). The callus formation was faster on such medium and resulted in formation of plumule and the shoot. Grewal (42) studied regeneration behavior in *Bunium persicum* and reported that BA in combination with NAA evoked maximum regenerative response with three types of calli- pale yellow friable: green compact organogenic and white non-embryonic. They were able to show that *Bunium persicum* undergoes both embryonic as well as organogenic regeneration. They extended the investigation regarding the embryogenesis in aggregated liquid cultures and observed that the MS medium supplemented with 2,4-D and kinetin were essential for the establishment and maintenance of embryonic competence of liquid cultures. Agar supplemented with kinetin only was required for germination of embryos and their conversion into plants. Ebrahimi et al. (43) used embryo explants in case of cumin using B5 medium containing IAA 90.2 mg/L), BAP (1 mg/L) or NAA (02 mg/L), and BAP (0.2 mg/L); they obtained a large number of shoots in a short time without any sub-culturing. Simultaneous root formation and shoot regeneration from callus was also achieved by Valizadeh et al. (44) using hypocotyl explants on full strength B5 medium supplemented, micro-nutrients, and various growth regulators, such as NAA (0.1, 1 and 2 mg/L), 2, 4-D (0.1, 1 & 2 mg/L), and kinetin (0, 0.5, 1,2 and 4 mg/L). Callus initiation was observed within 20 days after explant transfer to medium. The concentration of PGR's had significant affect on callus induction and size. The best treatment for callus induction was B5 medium containing 0.1 mg/L 2,4-D and 2 mg/L kinetin or 1 mg/L NAA and 2 mg/L kinetin. For regeneration medium containing NAA (1 mg/L) and kinetic (4 mg/L) was optimum. Higher root induction was achieved by using B5 containing NAA (1 mg/L) and kinetin (2 mg/L), while the highest somatic embroyogenesis was observed on medium containing 2,4-D (2 mg/L). The method was a refinement over existing protocols as it leads to simultaneous callus induction and root/shoot initiation without sub-culturing and was faster (total period 50-60 days). We also used various explant sources, such as model segments, internodal segments, leave sand inflorescence, and various combination of auxins, such as 2,4,-D, IBA, NAA, and cytokinins. To optimize the culture conditions for callusing, organogenesis and production of plantlets, elements such as kinetin and BAP were used. For callusing MS medium, IBA was supplemented at (1×10^{-5} M) and 2; 4-D (2×10^{-6} M). Two types of calli viz., nodular green organogenic, and white friable non-organogenic were produced. The calli remained active even after 10 sub-cultures, with optimum callus size found to be 1-2 g. The smaller size calli (<1 g) did not survive, whereas, large size calli (>2 g) caused difficulties in handling during sub-culturing. For shooting, MS medium containing kinetin (1×10^{-5} M) and NAA (5×10^{-6} M) was found to be most suitable, whereas, root initiation ½ MS medium containing IBA (1×10^{-7} M) and NAA (3×10^{-7} M) was optimum. The rooted plantlets were cultivated for 30 days on rooting media and micro-tubers of pinhead size were developed. In our study, we observed that the color of callus was an important indicator of morphonegic activity. Thus, the calli, which would in later sub-culturing process turn out to be morphologically inert, could be rejected earlier. Grewal (42) had also reported induction of microtubers by using MS-medium with different levels of kinetin and sucrose. One-half MS medium could induce more conversion of somatic embryos (75%) into longer and tubering shoots, even though tuber size was only one third of a full-grown medium size tuber. There was a dose dependent relationship of tuber induction with kinetic, with highest tuber formation at 1×10^{-8} kinetic level. All the plantlets produced tubers with average weight of 32.5 mg;. similar dose dependent relationship was observed in case of sucrose concentration. While plant conversion and shoot growth was maximum at 30 g/L sucrose, the tuber weight was highest at 60 g/L sucrose. The number of tubering shoots also increased to 90% at this level of sucrose.

Post-harvest management and added value

The medicinal and culinary value of Kala zeera is due to various components in its essential oil. It has been reported that there is considerable quality deterioration due to improper handling as evidenced by the low percentage of oil production in farmer's processed seed samples (3-5%) as oppose to 14% maturity. In Kala zeera, the percentage of essential oil varies appreciated with the state of growth, type of umbel, method of harvest, method of drying, picking, packing, and marketing. Improper post-harvest practices causes quality deterioration, contamination, as well as pest microbe infestation. Among various factors, the stage of harvesting is reported to have significant bearing on yield and essential oil recovery. Delaying harvesting may result in yield losses up to 21% (3). This is especially the case in areas like Gurez, where harvesting season of Kala zeera is accompanied by strong winds. Therefore, it is advisable that the crop must be harvested once the umbels turn yellowish, in the early hours of the morning. For essential oil recovery, harvesting at 90% maturity gives the highest oil recovery (19). The reduction in moisture content with delayed harvesting also affects essential oil recovery. Therefore, it is suggested that for oil recovery, seeds must be harvested at 15-20% moisture as it yields 13-16% oil, as against less than 10% moisture yielding only 6-8% oil. However, it is not the case for seeds to be harvested for subsequent sowing; itis recommended to pick nature umbels with moisture content of 10-12% (3).

Traditional drying under sunlight usually takes 8-11 h and deteriorates the quality. The scientific drying using solar dryer takes only 2-3 hours and yields higher oil recovery (6-8%). The solar dryer consists of a drying tray with mesh wire bottom and a roof on top to protect from weather, dirt, and dust. A glass shield with corrugated black-coated galvanized absorber creator airflow through convection, which raises the output temperature up to 48 ^{o}C. With a glass area of 0.75 m^{2} and tray size of 0.75 × 0.35 m, it has a capacity of 3-4 kg.

Conclusion

Kala zeera has emerged as a potential high value crop for the hilly areas of the Himalayan region including the high altitude areas of the Kashmir valley. However, relentless harvest of seeds has endangered its existence. There is need to effectively pursue conservation efforts to save this high value medicinal plant. Efforts are underway at SKUAST-K and elsewhere to standardize the crop management practices as well as technological interventions to harness the potential of this crop.

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