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Variable expression of anthocyanin in flower and stem of coriander (*Coriandrum sativum* L.): Breeding implications

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Abstract

Coriander (*Coriandrum sativum* L.) is an important seed spice crop widely cultivated in India and the world for flavouring and seasoning of food and food products. Morphologically, two distinct kinds of plants are observed in coriander, one having light green stem having purely white flowers and the other with green stem having somewhat light purple blush on it bearing pink coloured flowers. Anthocyanin is the pigment responsible for this variable colouration of coriander stem and flower. This paper aims to discuss the variability observed in flower and stem colour of coriander and its possible ways of exploitation for crop improvement in terms of high germination, yield, quality and stress (pest and cold) resistance.

Keywords: Coriander, anthocyanin, yield, quality

1. Introduction

Coriander (*Coriandrum sativum* L.) is an important seed spice crop widely cultivated in India and the world for flavouring and seasoning of food and food products due to volatile oil and aroma in its seed and leaf. In India, it is mainly cultivated in Rajasthan, Gujarat, Madhya Pradesh and Andhra Pradesh. In Rajasthan, the humid south eastern plain zone (zone V) comprising of districts of Kota, Baran, Bundi and Jhalawar contributes around 94 percent to the total area and production of coriander in the state.

Morphologically, two distinct kinds of plants can be seen in coriander, one having light green stem and the other with a somewhat light purple blush on it. The former plants have purely white flowers, while the latter have pink coloured flowers (Pruthi, 2001) [14]. Besides these, a few genotypes with purple stem and white flowers have also been observed in the coriander germplasm stock of South Eastern Rajasthan but the plants with purely green stem bearing pink flowers have not been observed. The natural occurrence of these types possibly indicates the absence of tight linkage between green stem and white flowers but the pink flower colour can be said to be tightly linked with purple stem. The pigment responsible for variable colouration of coriander stem and flower seems to be anthocyanin. Although pigmentation in seeds or flowers has been well dissected at molecular level in several plant species, the genes controlling natural variation in anthocyanin traits in coriander are not completely understood.

The coriander flower colour or the colour of the petals is said to be very much influenced by the environmental conditions. During unfavourable weather conditions, the petals of the plants can accumulate so much anthocyanin so as to appear dark purple or violet. Diseased plants in particular also show more anthocyanin in the flowers, as well as in the stems and leaf sheaths. The ability to synthesize anthocyanin is obviously genetic, and to some degree is strengthened in its expression by environmental or physiological stress, as it is known in many other plants. The ability of coriander to form anthocyanin is due to one dominant gene (Romanenko, 1990) [18]. The mutation towards the recessive state, which causes white flowers, may have happened spontaneously and independently. This character can be used as a morphological marker in coriander breeding and can be evaluated before the plants flower. This paper aims to discuss the variability observed in flower and stem colour of coriander and its possible ways of exploitation for crop improvement.

2. Increasing pollination and yield

Coriander is a cross pollinated crop. Honey bee is the major pollinator of coriander including other insects. The floral colour may act as an attractant for the pollinator, thereby increasing the chances of percent pollination and ultimately the yield. Flowers of seed spice crops are attractive in colours and also contain high nectar and fragrance, which attract large numbers of insects including honey bees (Krishna Kant *et al.*, 2013) [7]. The relative abundances and foraging behaviour of honey bee species on seed spices was studied by Krishna Kant *et al.* (2013) [7] and reported that *A. florea* was most active on ajowan followed by dill, anise and nigella. *A. dorsata* was most active on nigella than dill, whereas *A. mellifera* preferred more on nigella and anise crops. Meager reports are available regarding the correlation between the coriander flower, colour variations (pink and white) and the pollinator population, percent pollination and seed setting. If the plant with a certain flower colour seems to favour the honey bees activities like foraging, collection of nectar and pollen, pollination etc. and ultimately results in increased yield, those genotypes can be used in breeding programmes as donors for higher pollination and yields.

Therefore, information about the bees count on the different coloured coriander flowers and how this affects pollination efficiency and crop yield is essential; unfortunately, few studies to date include such information. Flower colour may influence choice. Yellow and white flowers were found particularly attractive. In view of this, flowers of cross pollinated entomophilous crops like coriander should be modified to make them highly attractive in terms of morphological and biochemical features, quantity and quality of pollen and nectar, and by elimination of any floral barriers. The difference in honey bee population and activity with respect to variable flower colour of coriander remains to be seen and if any difference is found in terms of extent of effective pollination ultimately affecting the seed yield, breeding in favour of that specific flower colour can be initiated.

Besides increased coriander yield, apiculture along with agriculture has also emerged as an effective means of raising farmers' income. The bees can generate 500 kg of honey from one hectare farm of coriander; therefore, keeping honey bee boxes in coriander fields with plants of flower colour preferred by the bees and other insect pollinators can also help in increased production of honey. The effect of morphological and biochemical variations of the crops cross pollinated by honey bees and the quality of honey produced has not been adequately studied. Therefore, besides the quantity, the quality of honey as influenced by the flower colour of coriander could also be studied.

3. Insect resistance

Coriander attracts large number of predators, parasitoids and pollinators due to presence of high quantity of nectar and volatile oil emitted from the plant. On the contrary to attracting pollinators, floral variation with respect to morphological (colour) and biochemical (nectar) features may also contribute to non-preference mechanism of insect resistance. Host plants exhibiting this type of resistance are unattractive or unsuitable for colonization, oviposition or both by an insect pest. This type of resistance is also termed as non-acceptance and antixenosis. Nonpreference involves various morphological and biochemical features of host plants. Morphological features include plant colour while biochemical features, which are believed to be more

important than morphological and physiological factors in conferring non-preference, include the concentration of biochemicals in the plant, for eg., the concentration of essential oil in coriander seed and plant.

Aphid (*Hydaphis coriandri*) is a serious insect pest of coriander and its attack on the crop is maximum during flowering and seed development. This insect sucks the sap from the soft plant parts such as stem, flower and seed causing either the complete failure of seed formation or very undersized seed causing significant reduction in yield. A population of 55-70 aphids/5 plants during flowering could reduce the yield by 50 percent (Jain and Yadava, 1989) [6] while more than 200 aphids per plant can reduce the yield of 2.0 qt/ha. (Jain and Yadava, 1986) [5]. The relationship between coriander flower colour and aphid population has not been worked out and hence demands due attention. If any relationship is observed between these two, the preferred flower colour for aphid infestation can be effectively used as an infector row in entomological/breeding experiments while the other colour can also be used as morphological marker for insect resistance, and also as a biological method of insect pest management.

4. Role in plant defense

Anthocyanins are bioactive flavonoid compounds that have been recognized to be beneficial to human health against many chronic diseases, regulating antioxidant enzymes and modulate lipid metabolism for averting cardiovascular disease (Routray and Orsat, 2011) [19]. Anthocyanin accumulation in the plant is stimulated by several factors such as light intensity, low temperature, drought, nitrogen and phosphorus deficiency (Meyer *et al.*, 1973; Hopkins, 1999) [12, 5], UV radiations (Reddy *et al.*, 1994) [16], Pathogens (Hipskind *et al.*, 1996) [4], plant growth regulators such as cytokinin (Deikman and Hammer, 1995) [2], gibberellins (Mealem- Beno *et al.*, 1997) [11], ethylene (Woltering and Somhorst, 1990) [23] methyl jasmonate (Franceschi and Grimes, 1991) [3] and salicylic acid (Latunde-Dada and Lucas, 2001) [9]. Rahimi *et al.* (2013) [15] reported that salicylic acid and micro elements, especially zinc can be effective in improving anthocyanin biosynthesis in coriander. Increase in anthocyanin concentration of coriander leaves as antioxidant is important for improvement of nutritional value and human health. Anthocyanin pigment is said to play an important role in plant's defense against abiotic and biotic stresses. If the variable concentration of anthocyanin in different stem and flower coloured plants and their respective response towards stresses can be ascertained, it can be exploited for development of abiotic and biotic stress resistant genotypes.

5. Crop quality (essential oil content)

Coriander is commonly harvested for the spicy, aromatic seeds which are ground as an ingredient of spice mixtures, or are steam distilled to extract aromatic "essential" oil. The oil is used in prepared or processed foods and toiletries. The essential oils are semiliquid well known as fragrant oils and steam volatile liquids. High quality coriander seed has essential oil content between 0.4 to 1.4 percent. The finest quality oils contain 60 to 70% linalool, a compound which produces much of the characteristic coriander flavor. Breeding coriander for quality in terms of higher essential oil content has always been an important breeding objective. Although, studies report the large seeded coriander to have a lower essential oil and linalool content than the small seeded types but meager reports are available pertaining to the

variation in the essential oil content in seed or any other plant part on the basis of flower or stem colour of coriander. Higher essential oil content was reported in white flower coriander lines as compared to purple flower, purple stem genotypes (Verma *et al.*, 2014) [22]. Salem *et al.* (2014) [20] studied the chemical composition and antioxidant activities of the essential oils and anthocyanin of *Borago officinalis* flowers in two regions and observed difference in essential oil yield at two different regions during flowering stage. During the development of borage flower, anthocyanin yield increased significantly from budding to full flowering stages in the two studied regions. A notable variability was found among the anthocyanin and essential oil concentrations and their antioxidant activities between the two studied regions, indicating a strong influence of the degree of maturity on metabolite production. Since the anthocyanin and essential oil content in medicinal and aromatic plants has been reported to be influenced by stage of plant growth and geographical region, therefore, it needs to be worked out, whether variability exists in quality (essential oil content) with respect to plant morphological features (stem and flower colour) and if it is so, which colour is better in terms of quality so that it can also be used as a morphological marker for crop quality.

6. Early and higher germination rate

Coriander shows slow germination as it takes around 10-15 days to germinate after sowing. Besides slow germination, it also shows lesser germination percent (65-70%) as compared to other crops. The farmers, therefore, uses nearly 50 percent higher seed rate of coriander so as to ensure optimum plant stand but this in turn, increases the seed cost and disease incidence. The slow germination is possibly due to presence of phytochemicals like coumarins in the plant. Phytochemicals are chemical compounds occurring naturally in the plant kingdom and responsible for the organoleptic properties of the natural sources in which they are present. It generally refers to those chemicals that may have biological significance, for eg. Carotenoids, flavonoids, coumarins etc. Coumarins can be found in the integument of seed, fruits, flowers, roots, leaves and stems. (Maria *et al.*, 2015) [10]. The relative concentration of coumarins in plants of different flower colours needs to be evaluated to study if there's any difference in the different stem and flower coloured plants and the corresponding concentration of coumarins, ultimately differing in days to germination and percent germination.

7. Allelopathy

Allelopathy is a biological phenomenon in which plants affect each other, positively or negatively, through the production of allelochemicals released into the environment (Rice, 1984.). One of the main possibilities of exploiting suppressive allelopathic effect in agriculture is its implementation in integrated plant protection systems as an alternative measure of weed control. Allelopathic plants with high potential are considered as a source of new molecules with herbicidal action (Bhowmik *et al.*, 2003) [1]. Singh *et al.* (2019) [21] studied the allelopathic effect of aloe vera on its associated weeds and observed that the highest extract concentration of aloe vera reduced germination of black nightshade (*Solanum nigrum* L. emend Miller) and dayflower (*Commelina benghalensis* L.) for 19.6%. Khaliq *et al.* (2011) [8] reported that seed morphology and physiology could also affect difference among tolerance as well as the ability of weed species to adapt to different unfavorable conditions while Petersen *et al.* (2001) [13] suggested that seed size can

influence response to allelochemicals with smaller seeds being more susceptible to negative phytotoxic effects. Similarly, coriander also shows allelopathy and difference in allelopathic potential of coriander plants with respect to different anthocyanin concentration in stem and flowers should also be worked out.

8. Conclusion

In view of the various aspects of the variation in the stem and floral colour for exploitation in coriander breeding programme as discussed above, it can be concluded that further detailed study should be done with respect to anthocyanin variation in coriander plants to develop desired coriander genotypes for high germination, yield, quality and stress (pest and cold) resistance.

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