Colour polymorphism in *Acrida exaltata* and *Acrida gigantea* in par with seasonal changes in the habitat background

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Introduction

Generally, grass hoppers are either green or brown with the exception of a few being brightly coloured found to live either on grass or on bald land patches. Some species live on short plants too and a few grasshoppers are capable of change body colour resembling their back ground. One of the basic features of insects is the body colour specific to species with a definite pattern of pigment distribution but this definitive colour pattern of insects is also variable due to influence of several factors (Gilbert and Epel, 2009). Adaptation to a kind of habitat by camouflage is a common strategy through change in body colour in insects. Though the body colour pigmentations are determined by the genetic composition (Tool and Aquadro, 2007) and its regulation (Gompel *et al.*, 2009) often it is modified by environment. Grass hoppers exhibit colour polymorphism with a degree of intra specific variability is recorded by several workers (Hochkirch *et al*., 2008; Dieker *et al*., 2018; Edelaar *et al.*, 2008; Imene *et al*., 2019; Uvarov,1939; Fisher,1939). The body colour variation is brought about by both biotic and abiotic factors. The biotic factors that instigate colour variation include predation and crypsis (Olendorf *et al*., 2006), selection, survival and evolution (Andre´s *et al.*, 2002; Gray and McKinnon, 2002). Abiotic factors responsible to bring variations in morphological colour include temperature, humidity and food resource, due to these pigments responsible for thermoregulation (Forsman, 1997) and microhabitat utilization (Ahnesjo and Forsman, 2005) are developed. Changes in the morphological colour variations in grasshopper *Acrida exaltata* and *Acrida gigantean*, with the change of season in this part of the country has not been explored. These two species of grasshoppers live on short grass patches as sympatric species. In this study we have observed and recorded the occurrence of exclusively green coloured morphs during rainy season when the grass is lush green and light yellowish brown coloured, dark brown pigmented grasshopper morphs of these two species during winter when the grass was either totally dry with straw colour or partly dry with grey colour with dark patches on the withering grass blades.it has also been recorded, that the different body colour morphs of these two species of hoppers with seasonal changes in the environment in their natural habitat. The study was carried out at different locations, and has been analysed w.r.t the changes in habitat at each site. *Acrida exaltata* and *Acrida gigantea* are greenish in colour predominantly inhabit short green grass. Both species are bivoltine, first generation appears during rainy season and the second generation appear during winter season. The two species have narrow range taxonomical and morphological variation, distinguished by presence of white line on the sides of thoracic region in *A. exaltata* and presence of a red line on the sides of thorax in *A. gigentea*. Both the species have a narrow molecular variation, compared to other congeneric grass hoppers (Jayashree and Channaveerappa, 2016).

Material and methods

Observation of the phenotypic variations in two species of grass hoppers were recorded between the months June and September and last week of November to end of March comprising rainy season and winter respectively (Table 1 and Figure 1). Two species of congeneric grasshoppers *A. exaltata* and *A. gigantia* were collected from the natural habitats of three geographical regions namely, Mysuru 12.295^{0}N and 75.6304^{0}E, University of Agriculture sciences campus, Dharwad 15.4589^{0}N and 75.0078^0 E and from Kushalnagar 12.4602^{0}N and 76.6394^0 E in Kodagu region.

Dharwad and Kushalnagar are located at about distance 450 km and 100 km from city of Mysuru. In Mysuru, two areas with different characteristic features were selected for observation of phenotypes of both the species of grass hoppers. One, the Manasagangotri campus that had fast drying grass with no water body in the vicinity, the other Karanji lake area that had slow drying green grass patches mixed with dry grey grass because of occasional watering and a lake located nearby at about fifty meters of observation site but due to severity of the cold temperature there was drying of grass. The nature of other three sites were entirely different. The grass patches were completely dry and grey in the months of mid-November to April of coming year by this time reproductive season of the winter population ends. Regular rainy season starts mid-June in these localities and induces the appearance of green grass. The change nymphs of these two species emerge those are exclusively green and develop in to green varieties of grass hoppers. Edit sentence- too long and not clear. In contrast to this, only light brown nymphs appeared during winter at three localities other than Karanji lake where green nymphs emerged during winter turned in to green grass hoppers with white or brown patches. Each morphological type of grasshoppers marked in to type for green polymorphs, and brown morphs having different range of pigment patterns. The on field distance covered during observation/collection of these insects, to record the density of distribution in both the seasons, measured using the step tracker app on android phone and the counted numbers are shown in a graphic representation.

Observations

These two species of grass hoppers appear as green morphs during rainy season and no alternate phenotype has been recorded (Fig.1a-b), the generation of these two species appearing in winter have different coloration on the body and marking on fore wing and thorax. In this season these grasshopper were found to appear in five distinct morphological forms, ranging from light colour mixed white line along the fore wing with brownish grey body colour (Fig.2b-f), brownish grey body colour without any marking (Fig. 2b), brownish grey body colour with dark brown patches (Fig.2c), brownish grey body colour with dark or brown granular structure on the wings (Fig.2d-f), these morphological variations appeared in a characteristic background colour. We have encountered such phenotypes in the same species of insects collected from Coorg and Dharwad regions also with the similar features of their natural habitat where the insect found. In Karanji lake where green nymphs emerged during winter turned in to green grass hoppers with white patches and without melanin pigments on the thoracic region as in other two regions studied (Fig.1d).

The climate conditions during winter were cold, dry, and less humid and there were no rains. A continued dry phase turned grass blades, in to grey, greyish brown, leading to formation of black or brown spots on the dried grass blades, hence green grass was completely absent. The temperature at night (average 18-19 °C) was lower than the average day temperature (average 22-24 °C). The number of grasshoppers of both the species were found to be more in rainy season and scanty during winter/dry season (Fig.3).

All the morphological types resembled the back ground colours of grass of that season. The changes in the body colour may help the insect to escape from the view of the predators like lizards and birds etc.

Discussion

Adaptations to habitat through camouflage for protection are a common strategy in nature. Camouflage prevents the organism from getting detected by the predator. Such camouflages have been reported in other grasshoppers too. Further, positioning behaviour in a novel habitat by individual color variation of (Villalba Baños *et al*., 2017) *S. azurescen*, with respect to climatic change in aridzone grasshoppers. Phenotypic plasticity in two ground grasshoppers (Hochkirch *et al*., 2008) *Tetrix ceperoi*and *Tetrix Subulata*, two colour polymorphism in an alpine grasshopper with seasonal changes (Dieker *et al*., 2018). Colour polymorphism with genetic basis appears too frequent by recurrent mutations (Fisher,1930; Huxley,1955). Not all cases of phenotypes need to be genetically controlled while some may due to phenotypic plasticity (Eberhard, 2003). In some of the orthopterans, the green-brown polymorphs have been found to be under the control of environment with a specific background and moisture, playing a key role during nymphal development (Dearn,1990; Rowell,1971). The green colour of grasshoppers is formed by tetrapyrales produced during regular nymphal moulting (Shamim,2014). Due to less moisture, dry conditions prevailed in the months of December and January. Presence of dry brownish background might have influenced regular sequence of pigments formation in developing nymphs, to molt into yellowish brown morphs of these two species of grasshoppers, to hide their existence. Such colour morphs of fore wings are recorded in the butterfly *Araschnia levana* in the spring and summer generation due to influence of changed conditions on developing pupal stages (Baudach *et al*., 2018). The phenotypes thus generated in adult *A. exaltata* and *A. gigantea* may be supportive to suit the dry grass background and protecting from the predation. In these two species of grasshoppers colour change is a slow process starting from nymph to adult stage. In the wild populations analysed, all the individuals exhibited a typical match between the grasshoppers and dry grass or green grass back grounds. These insects always preferred to live with the background supporting their hide. Such matching habitat choices in other grasshoppers has been interpreted in relation to directed gene flow and increased colour matching due to increased risk of predation has been explained by the studies on grasshopper species *S. azurescens* (Edelaar *et al*., 2008, 2017).

Environment influenced colour polymorphism is a more common phenomenon among insect (West and Hazel, 1979). Darker colour of the body in insects is due to melanin pigment manifests more in colder climates in majority of insects to absorb solar energy to maintain optimal body temperature (Wilson, 2001) and get protection from the pathogens (Watt, 1968) contrastingly in warmer conditions will have lighter body coloration (Gilbert *et al.,*1998) to avoid the risk of overheating. The phenotype of an insect can also be influenced by environmental cues prevailed during nymphal stages of ontogeny such as colour of the substrate as examined in ground hoppers *Tetrix subulata* and *T. ceparoi* (Hochkirch *et al*., 2008) and confirmed basic colour and colour pattern are influenced by back ground. The Karanji lake population manifested a green phenotype with white patches has to be assumed was an indicative that dark brown pigment synthesis blocked as it contrast the green background of slow drying grass and brown could be a mismatch. Among insects it is well known that the dark pigment on the wing and thorax is due to melanin pigment (Shamim, 2014) and in a few insects such as butterflies the neuro endocrine interaction during embryonic development induce more melanin pigment synthesis (Gilbert and Epel,2009) Therefore, in Karanji lake population the white patches on the thoracic region of green phenomorphs may be due to non-production of dark brown pigment. Thus interaction of developing nymphs with the slow drying green grass back ground might have developed a phenotype to match the back ground.

Colour polymorphism in winter population of the two grasshoppers with dark pigments combined with light or brown colour may help in increasing their camouflage in the preferred habitat, also the melanin pigment help in absorption of solar energy to perform physical actions like jumping. Melanin pigments predominantly found on thoracic region and melanin granules are spread on femur of hind legs where the energy generator gadget of grasshoppers are located where as in rainy season the grass is more green the body colour too appeared green in these two species of grasshoppers.

Roonwal (1977) and Uvrov (1966) have discussed the significance of body colour changes in grasshoppers giving presumed causal agents and evolutionary trends for these changes in morphology though these authors have recorded two phenotypes in the genera Acrida, the detailed analysis gives to the natural background and seasonal changes are not given. This colour matching with the back ground may help in survival and perpetuation of these species if it so stand as good example of survival strategy, yielding more relevance to this study.

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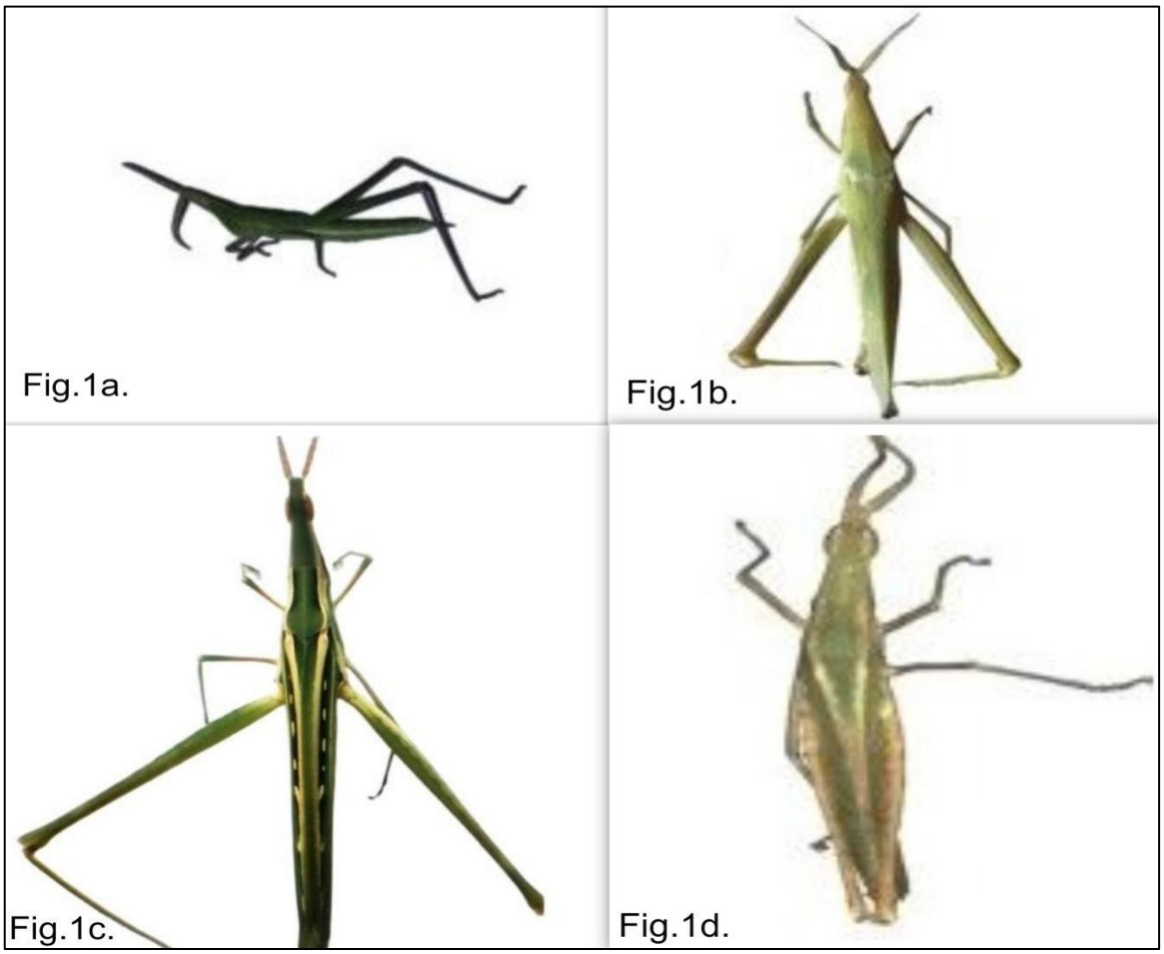

Fig. 1a. Green Nymph (common in rainy season/rare in winter. Appears both the species *A. exaltata*, *A. gigantean*, **Fig.1b.** Green morph - *A.exaltata*, **Fig.1c.** Green morph polymorphism in white band and discontinuous white pigment on sides, **Fig.1d.**Green morph *A. gigantean* - white bands but broken white line missing

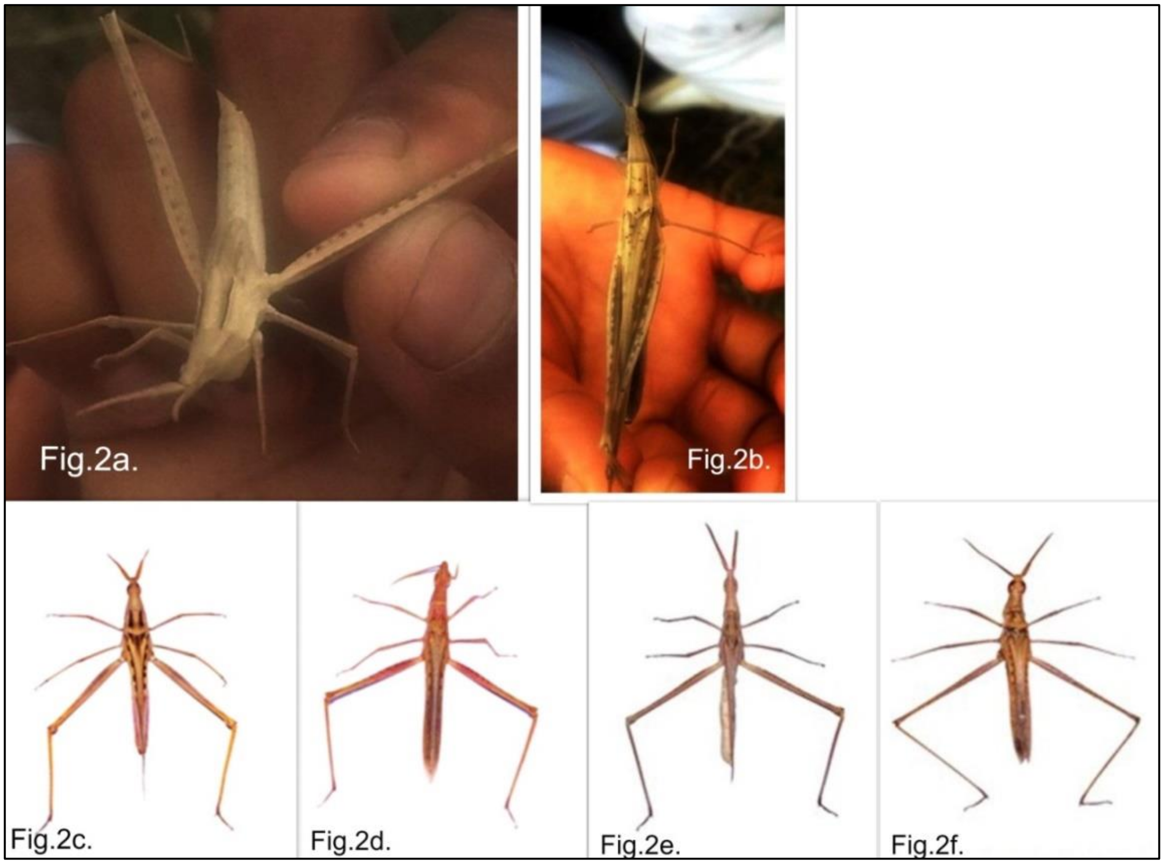

Fig. 2a. Brown nymph: appears in winter season seen in both the species, **Fig. 2b.** Brown morph : *A. exaltata* with least expression of black bands on thorax and sides of wings., **Fig. 2c.** Brown morph: *Aexaltata* deep dark bands on prothorax, inverted triangle black band and broken dark lines on sides, **Fig. 2d.** *A. gigantea* dark band of small size on thoracic regions and sides of wings, **Fig. 2e. and 2f.** *A. gigantea*- With two small thoracic bands the inverted black band missing but has small side bands.

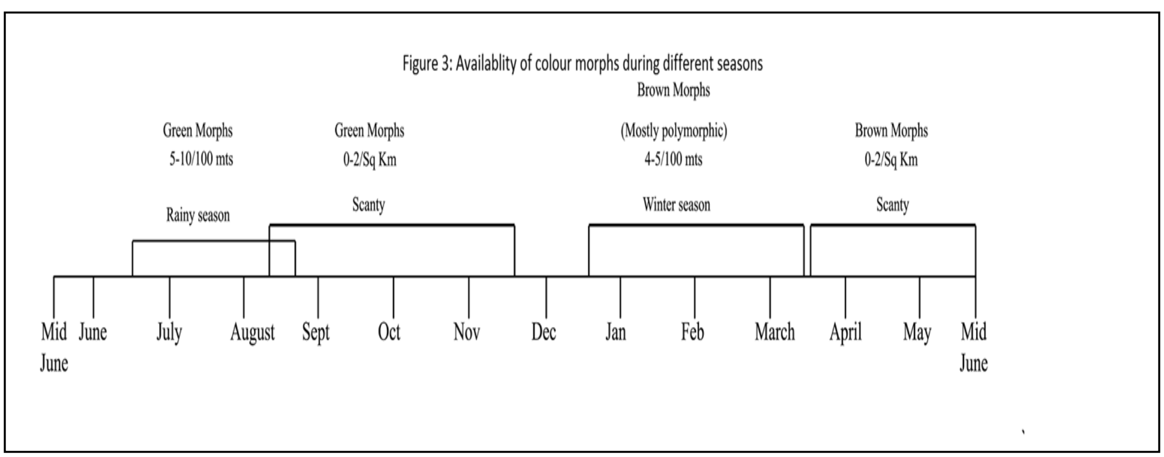

Fig. 3. Availability of colour morphs during different seasons

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