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Diversity, Abundance and Infestation of Bruchids on Stored Pulses in Karnataka

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ABSTRACT

The survey was conducted to assess the diversity, abundance and infestation level of bruchids in pulse storages across 13 locations in Karnataka. A total of 23 stored grain samples representing eight pulses were collected from small and large scale stored conditions. The samples were observed for grain moisture content and infestation parameters. The grain moisture content was found within the recommended range for safe grain storage (< 12 %). The associated bruchids were identified and species diversity, abundance and dominance was computed. The bruchids were belonged to five species of genus, *Callosobruchus* (*Callosobruchus chinensis* L., *C. maculatus* F., *C. analis* F., and two were unidentified *Callosobruchus* spp.) which were found infesting different pulses. Species diversity was found higher in small scale storage conditions (H=0.56) than large scale storages (H=0.39). Among the bruchid species, *C. chinensis* (~65 %) was found to be most abundant species at maximum locations and crops followed by *C. maculatus* (~53 %), however, under large scale storage conditions, *C. analis* (54 %) was abundant. The most dominant species under large scale storages was *C. analis* (d=0.54), whereas, *C. maculatus* (d=0.45) was found to be most dominant under small scale storages. The seed weight loss was influenced by egg and adult density rather than per cent infestation and damage. Interestingly, higher grain moisture and prolonged storage duration were found influencing infestation and grain damage significantly. This study opens further window to understand the bruchid species infesting stored pulses during different times of the year, present effective management options including natural enemies and the present level of susceptibility of bruchids to the monopoly chemical option Aluminium phosphide.

Keywords : Bruchids, *Callosobruchus,* Stored pulses, Diversity, Abundance, Infestation

PULSES are the cheapest source of proteins (20-25%) and other vital supplements *viz*., dietary fibers, complex carbohydrates, resistant starch, complex vitamins and minerals (Patterson *et al*., 2009). The bi-products of these crops can be utilized as cattle feed and fuelwood, they enhance soil fertility with symbiotic nitrogen fixation (72-320 kg per ha per year - DPD, 2018), add organic matter to the soil, enhance phosphorous availability (Sardana *et al.,* 2010) and most importantly these crops can be better accommodated in diversified cropping systems.

Historically a major chunk of the Indian population fulfils protein requirements by consuming pulses regularly. The demand for pulses increased tremendously during the last five decades with the exponential population surge, whereas, the pulses production during this period has increased only by 2 fold as against 3.5 fold increase in population (Verma *et al.* 2020). Accordingly, the efforts to meet the ever-increasing demand were undertaken following significant efforts from research institutes along with appropriate government policies. As a result of these all-around efforts, the country has achieved record production of pulses attaining self-sufficiency during the past five years. Today, India is one-third producer of pulses globally with an estimated 25.58 mt production of pulses during 2020 (Anonymous 2021).

The unprecedented hike in prices of pulses between 2011-2014 followed by a demand-driven record pulses production between 2015-2020 forced the Government of India to propel buffer stock of pulses at various central (CWCs) and state (SWCs) sponsored warehouse godowns located across 400 locations (Economic Times, 2017). Apart from these godowns, the pulses are also being stored at medium to large scales by national (NSC) and state (SSC) seed corporations, short-time farm and household reserves.

Storage of pulses following improper storage protocols for longer period, invite the infestation of several species of stored grain insects (SGIs). Among the stored grain pests, the bruchids or pulse beetles, are the important group that infest pulses in field and storage. However, the damage is realized only in storages due to their continuous perpetuation across the storage period (Revanasidda *et al.,* 2020). Bruchids are comparatively smaller insects (1-6 mm) belonging to the sub-family Bruchinae (Chrysomelidae: Coleoptera) which include ~1700 species described under 62 genera. Among these, 30 species are recognized as devastating storage pests on different pulse crops worldwide, whereas, 9 out of 30 species are cosmopolitan pests (Mishra *et al.,* 2017). The genus *Callosobruchus* with 16 described species is considered to be predominant among the bruchids infesting stored pulses. In India 108 species of bruchids representing 11 genera have been reported (Bano and Gupta, 2015), among which three species *viz*., *C. maculatus, C. chinensis* and *C. analis* are ubiquitous on various stored pulses (Sengupta *et al.*, 1984; Tuda, *et al.,* 2006). Bruchids can adversely affect the quality, quantity, and nutrition of stored pulses, and pose a major threat to food security. The total grain losses due to these insects were reported between 4 to 60 per cent and it may reach up to cent per cent, if timely interventions were not taken (Mishra *et al.*, 2017).

Karnataka is one of the major pulse growing states in India and ranks 4th with nearly 11 and 8 per cent contribution to the national area (28.96 lakh ha) and production (15.98 lakh tonnes), respectively, after Madhya Pradesh, Rajasthan and Maharashtra (Anonymous, 2021a). Pigeonpea (9.93 lakh ha area & 6.67 lakh tonnes production) and chickpea (11.51 lakh ha area & 6.57 lakh tonnes production) are two leading pulses cultivated across the state followed by mungbean, horsegram, urdbean, cowpea and other pulses for vegetable purpose (Anonymous 2021a). Harvested pulses are stored at warehouse, farm and household level across the state and are infested by pulse beetles. The studies related to existing abundance and diversity of bruchids infesting pulses, extent of infestation and damage to grains are scanty. Hence, in the current study we aimed at understanding the diversity, distribution, abundance and infestation of bruchids on different stored pulses across Karnataka.

Material and Methods

Sampling of Infested Stored Pulses

Bruchid infested stored grain samples (250-500 gram) of various pulses were drawn from different storage conditions from thirteen locations spread across Karnataka state (Fig.1). The storage conditions represented both small (up to ten quintals: household/ kitchen / farm groceries store reserves) and large (more than ten quintals: farm / warehouse godowns) scale grain reserves. A total of twenty-three infested samples were collected from thirteen selected locations. The grains samples represented eight pulses namely pigeonpea, chickpea, mungbean, horsegram, cowpea, urdbean, mothbean and limabean. The passport information such as location, crop stored, source of grains, type of storage, quantity stored and duration of storage are described in supplementary Table 1.

The sampling method included collection of infested samples through 'direct collection' as well as through installation of 'grain traps'. Direct collection of infested grains was done from all the thirteen locations, whereas, the grain traps (as per the specifications of Naveena *et al.* 2015) were installed at seven locations where infestation was not available during personal visit.

Diversity, Abundance and Dominance of Bruchids

The infested samples collected were observed for emerged and emerging adult bruchids. In such infested samples where no adult beetles emerged after the sampling, were held for a few more days in laboratory to collect the late emerging adults. A

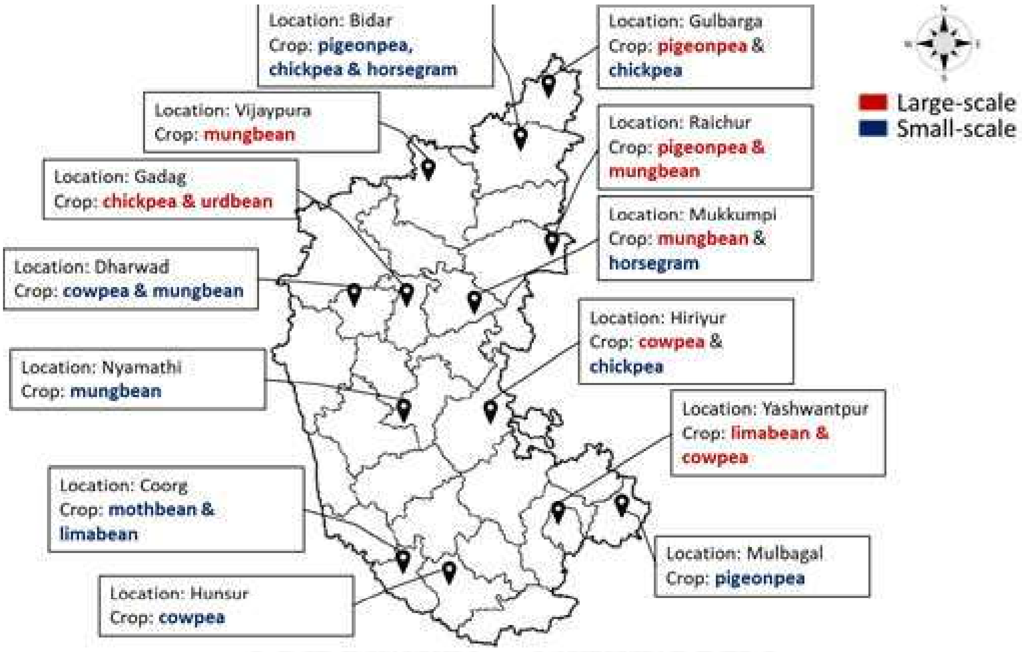

Fig. 1 : Sampling of bruchid infested stored grain samples of various pulses from thirteen locations of Karnataka

representative set of adult beetles were collected and pinned for identification through morphological characters based taxonomic keys (Arora, 1977; Rees, 2004; Kingsolver, 2004).

The total adult density of each bruchid species was enumerated all the collected grains samples and the data was used to estimate the abundance, diversity and dominance indices under small and large scale storage conditions.

The relative abundance of each species was estimated by counting the proportion of individuals of each species to the total number of individuals of all the species collectively in a sample and was expressed as percentage abundance of each species in relation to other species. *The species diversity* (H) of the bruchids was determined using Shannon-Wiener Index (Shannon and Wiener, 1963)

$$H = \sum pi \times \ln pi$$

Where pi is the proportion of the i^{th} species of bruchid among the total individuals of all the bruchid species observed.

Apart from this, *the dominance* (d) *of species* across the stored grain samples representing different locations was determined by the Berger-Parker dominance (1970) index 'd', which gives the proportion of the total numbers of individual bruchid in an environment that is due to the dominant species and was calculated by:

$$d = ni / NT$$

Where ni is the number of individuals of the i^{th} species on sampling date and NT is the total number of individuals in the sample.

Infestation Parameters

The required quantity (100 gram) of infested grain samples collected were brought to the laboratory and observed for existing level of bruchid infestation parameters like per cent grain-moisture, infestation, damage, weight loss and egg density per grain. The grain moisture was measured with Universal Digital Moisture Meter (Make: Indosaw®) following the manufacturer's protocol and expressed in percentage.

Grain infestation was recorded by counting number of grains with eggs out of the total grains present in

TABLE 1

Passport information on sampling of bruchid infested stored grains

Location	Crop	GPS coordinates (DMS)	Source of collection	Type of storage	Qty stored (Kgs)	Scale of storage	Storage duration (days)
Mukkumpi	Mungbean	15°25'42.6"N 76°23'05.9"E	Farm storage	Gunny bags	2400	Large	82
Gulbarga	Pigeonpea	17°21'35.9"N 76°48'57.2"E	ZARS godown	Gunny bags	2800		100
Yashwantpur, Bengaluru	Lima bean	13°01'21.7"N 77°32'46.9"E	APMC godown	Gunny bags	4100		54
Yashwantpur, Bengaluru	Cowpea	13°01'21.7"N 77°32'46.9"E	APMC godown	Gunny bags	2900		11
Hiriyur, Chitradurga	Cowpea	13°57'31.2"N 76°37'19.3"E	APMC godown	PPW and gunny bags	5300		42
Raichur	Pigeonpea	16°11'00.9"N 77°20'16.9"E	FCI godown	Gunny bags	69700		68
Raichur	Mungbean	16°11'00.9"N 77°20'16.9"E	FCI godown	Gunny bags	23000		107
Vijaypura	Mungbean	16°50'19.0"N 75°45'15.7"E	FCI godown	Gunny bags	11019		296
Gadag	Chickpea	15°25'17.2"N 75°38'22.1"E	CWC godown	PPW and gunny bags	2121		265
Gadag	Urdbean	15°25'17.2"N 75°38'22.1"E	CWC godown	PPW and gunny bags	1780		39
Bhalki, Bidar	Urdbean	18°02'54.6"N 77°12'49.4"E	Dal mill	Gunny bags	93	Small	41
Bhalki, bidar	Pigeonpea	18°02'54.6"N 77°12'49.4"E	Dal mill	PPW and gunny bags	149		71
Bhalki, Bidar	Chickpea	18°02'54.6"N 77°12'49.4"E	Dal mill	Gunny bags	112		82
Mukkumpi, Koppal	Horsegram	15°25'42.6"N 76°23'05.9"E	Farm storage	Gunny bags	150		67
Coorg	Mothbean	12°24'53.1"N 75°44'48.2"E	Groceries store	Metal bin	200		28
Coorg	Lima bean	12°24'53.1"N 75°44'48.2"E	Groceries store	PPW	47		94
Dharwad	Cowpea	15°29'25.7"N 74°59'23.8"E	IIPR-RRC	Cloth bags store	5		82
Dharwad	Mungbean	15°29'25.7"N 74°59'23.8"E	IIPR-RRC	Gunny bags store	23		101
Nyamathi, Davanagere	Mungbean	14°08'59.9"N 75°34'05.6"E	Farmers mandi	Steel container	30		38
Gulbarga	Chickpea	17°21'35.9"N 76°48'57.2"E	ZARS godown	Gunny bags	780		128
Hiriyur, Chitradurga	Chickpea	13°57'31.2"N 76°37'19.3"E	Groceries store	Gunny bags	490		106
Mulbagal, Kolar	Pigeonpea	13°07'55.3"N 78°10'41.1"E	KVK, Tamaka, Kolar	Gunny bags	21		50
Hunsur, Mysore	Cowpea	12°18'32.5"N 76°17'31.4"E	Super market	PPW and gunny bags	17		39

100 gram sample and the infestation was expressed in percentage using the following formula:

$$\text{Grain infestation (\%)} = \frac{\text{Number of grains with eggs}}{\text{Total number of grains}} \times 100$$

The percentage grain damage was determined using the formula described by Khattak *et al.* (1995):

$$\text{Damage incidence (\%)} = \frac{\text{Number of seeds damaged}}{\text{Total number of seeds}} \times 100$$

The seed weight loss of grains due to bruchid feeding damage was estimated using the formula : described by Eker *et al.* (2018) and the weight loss was expressed in percentage using following formula:

$$\text{Seed weight loss (\%)} = \frac{n_2 - n_1}{n_2} \times 100$$

wherein n_2 is the weight of the fresh seeds and n_1 is the weight of damaged seeds.

The egg density per grain was estimated by counting the total number of eggs laid on 100 random infested grains and the total egg density was divided by 100 to get egg density per grain.

Statistical Analysis

All the data were subjected to arcsine transformation to stabilize the variance. The data on infestation parameters was subjected to non-parametric Kruskal-Wallis ANOVA was using SPSS version 25® to ascertain the statifical variation between the parameters recorded on samples between small-scale and large-scale storage conditions. The diversity and dominance indices were estimated in MS Excel version 2016.

Results and Discussion

Grain Moisture and Infestation Parameters

The infestation parameters varied considerably between the locations and crop samples (Table 1a & b).

Grain Moisture (%) : The grain moisture ranged between 9.2 ± 0.2 to 11.6 ± 0.46 per cent across different pulses. Higher grain moisture was observed in urdbean samples collected from Bhalki, whereas the lowest grain moisture was recorded from mungbean collected from Nyamathi. In general, the grain moisture did not vary significantly between samples (Kruskal-Wallis ANOVA 'H'=1.69, $P_{<0.05}$=0.18, N=69) as well as between large and small scale storage conditions (H=1.54, $P_{<0.05}$=0.21, n=30 and 39, respectively) and it was found within the range of recommended grain moisture (< 12 %) for safe storage of pulses (Gupta and Kashyap, 1995).

Adult density : The adult density varied significantly between samples (H=4.97, $P_{<0.01}$=0.008, N=69), however, it was not varied significantly between storage conditions (H=1.63, $P_{<0.05}$=0.2, n=30 and 39, respectively). The adult density was recorded on mungbean smaples collected from Vijayapura (356.67 ± 33.5) and the lowest density was observed on pigeonpea from Raichur (49 ± 7.94) (Table 1a & b).

Grain infestation (%) : the per cent grain infestation or oviposition varied significantly between the grains samples of pulses collected from different locations (H=7.65, $P_{<0.05}$=0.04, N=69), however, it did not vary significantly between storage conditions (H=0.01, $P_{<0.05}$=0.92, n=30 and 39, respectively). The lowest infestation was recorded in urdbean sample collected from Gadag (8.09 ± 0.39 %) and the highest infestation of 52.85 ± 2.46 per cent was recorded in cowpea collected from Dharwad. Under large scale storage conditions, the highest infestation was recorded on chickpea grains collected from Gadag (30.72 ± 1.8 %), whereas, the lowest infestation was found on urdbean sample (8.09 ± 0.39 %) from the same location. Under small scale storage conditions, maximum infestation was found on cowpea sample from Dharwad (52.85 ± 2.5 %) and minimum infestation was noticed in mothbean from Coorg (8.66 ± 1.96 %) (Fig. 2a).

Akintunde (2012) observed nearly 5.5 per cent grain damage due to bruchid infestation in collected cowpea samples. Silva and Costa (2016) observed bruchid infestation on cowpea (*C. maculatus*) and bean (*Zabrotes* sp.) in the range of 0 to3.7 per cent. Babrinde *et al.* (2016) recorded up to 80 per cent infestation due to *C. maculatus* in cowpea grain samples collected from four markets across Gbomoso Metropolis, South western Nigeria. Mannan and Tarannum (2011), in Jamalpur district, Bangladesh recorded. The highest infestation of bruchids on grains stored in gunny bags (13.8 %) followed by

TABLE 1A

Infestation parameters of bruchid infested stored pulses collected from different locations of Karnataka

Location	Crop	Grain moisture (%)	Grain infestation (%)	Egg density/ grain	Grain damage (%)	Adult density (numbers per 100 g)	Grain weight loss (%)	Species observed
		Mean ± SD of three replications of 100 gram each						
Mukkumpi	Mungbean	10.27 ± 0.15	21.54 ± 0.49	1.21 ± 0.18	7.97 ± 0.15	206 ± 7.94	21.19 ± 0.43	*Callosobruchus chinensis* L.
Gulbarga	Pigeonpea	9.4 ± 0.26	8.23 ± 0.45	2.94 ± 0.24	5.21 ± 0.57	51.67 ± 13.3	17.28 ± 3.22	*Callosobruchus maculates* F.
Yaswantpur	Lima bean	10.7 ± 0.51	20.85 ± 1.94	3.97 ± 0.36	7.86 ± 1.39	104 ± 16.6	22.14 ± 1.91	*C. maculatus* F.
Yaswantpur	Cowpea	9.4 ± 0.44	12.02 ± 1	2.88 ± 0.19	6.87 ± 0.8	241.67 ± 38.2	47.69 ± 2.27	*Callosobruchus analis* F.
Hiriyur	Cowpea	9.8 ± 0.2	15.37 ± 2.64	3.36 ± 0.39	4.47 ± 1.19	190 ± 35.1	58.64 ± 6.05	*C. analis* F.
Raichur	Pigeonpea	9.4 ± 0.36	8.26 ± 1	2.10 ± 0.34	7.53 ± 1.29	49 ± 7.94	8.86 ± 0.12	*C. analis* F.
Raichur	Mungbean	9.53 ± 0.61	17.08 ± 0.82	1.24 ± 0.14	10.25 ± 0.98	307.33 ± 16.8	24.66 ± 1.48	*C. chinensis* L.
Vijaypura	Mungbean	10.6 ± 0.2	22.63 ± 2.29	1.43 ± 0.06	13.69 ± 0.82	356.67 ± 33.5	35.39 ± 1.39	*C. analis* F.
Gadag	Chickpea	10.77 ± 0.35	30.72 ± 1.8	3.71 ± 0.46	10.43 ± 2.03	163.33 ± 26.54	12.97 ± 1.85	*C. chinensis* L.
Gadag	Urdbean	8.63 ± 0.64	8.09 ± 0.39	1.11 ± 0.19	5.31 ± 0.47	146.67 ± 9.87	37.58 ± 0.77	*C. analis* F.

Value in each cell denote mean values calculated from three replicative sub-samples (100 g each) from each crop sample

TABLE 1B

Infestation parameters of bruchid infested stored pulses collected from different locations of Karnataka

Location	Crop	Grain moisture (%)	Grain infestation (%)	Egg density/ grain	Grain damage (%)	Adult density (numbers per 100 g)	Grain weight loss (%)	Species observed
		Mean±SD of three replications of 100 gram each						
Bhalki	Urdbean	11.6 ± 0.46	24.21 ± 3	1.19 ± 0.2	7.42 ± 1.14	205.67 ± 22.37	48.74 ± 2.41	*C. maculatus* F.
Bhalki	Pigeonpea	10.33 ± 0.51	16.54 ± 0.9	2.37 ± 0.41	11.12 ± 0.87	159 ± 16.52	25 ± 0.81	*C. maculatus* F.
Bhalki	Chickpea	9.8 ± 0.56	17.41 ± 1.5	3.79 ± 0.33	11.34 ± 1.04	237.67 ± 29.96	36.61 ± 1.22	*C. maculatus* F.
Mukkumpi	Horsegram	10.17 ± 0.32	15.34 ± 1.1	1.31 ± 0.1	6.25 ± 0.24	167.33 ± 8.1	29.44 ± 0.98	C. Sp1
Coorg	Mothbean	9.23 ± 0.15	8.66 ± 1.96	1.18 ± 0.04	7.43 ± 1.7	216.67 ± 50.66	32.05 ± 0.19	C. Sp1
Coorg	Lima bean	11.2 ± 0.36	32.76 ± 4.41	3.92 ± 0.27	22.39 ± 1.89	275.67 ± 26.1	10.10 ± 0.55	*C. chinensis* L.
Dharwad	Cowpea	11.17 ± 0.45	52.85 ± 2.46	3.03 ± 0.17	43.87 ± 2.01	673.67 ± 105.2	26.79 ± 3.44	*C. maculatus* F.
Dharwad	Mungbean	9.77 ± 0.65	15.37 ± 2.05	1.23 ± 0.17	10.88 ± 0.3	303.33 ± 11.5	22.86 ± 0.44	*C. chinensis* L.
Nyamathi	Mungbean	9.2 ± 0.2	10.52 ± 1.1	1.23 ± 0.08	10.82 ± 1.35	297 ± 31.76	22.55 ± 0.5	*C. chinensis* L.
Gulbarga	Chickpea	10.93 ± 0.42	34.36 ± 6.5	2.89 ± 0.15	12.98 ± 1.22	201.33 ± 11.24	27.22 ± 1.31	*C. maculatus* F.
Hiriyur	Chickpea	10.57 ± 0.6	29.47 ± 3.6	4.06 ± 0.54	11.12 ± 1.03	207 ± 24.52	25.41 ± 3.23	*C. analis* F.
Mulbagal	Pigeonpea	9.4 ± 0.2	16.96 ± 0.85	2.6 ± 0.13	10.23 ± 0.91	156.67 ± 17.21	12.55 ± 0.31	*C. chinensis* L.
Hunsur	Cowpea	9.57 ± 0.57	21.12 ± 2.34	2.92 ± 0.69	4.95 ± 1.07	145.67 ± 20.1	39.07 ± 3.66	C. Sp2

Value in each cell denote mean values calculated from three replicative sub-samples (100 g each) from each crop sample earthen containers (13.5 %). The lowest infestation was observed in grains stored in plastic containers (8.3 %). The infestation rate recorded from the different stored pulse samples in the present study varied between the locations within the same crops, and between different crops depending upon the storage conditions, storage bags used and management practices adopted.

Grain damage (%) : The per cent grain damage varied considerably between stored samples of different pulses collected from various locations (H=6.3, $P_{<0.01}$=0.006, N=69), however, it was not varied significantly between storage conditions (H=0.67, $P_{<0.05}$=0.31, n=30 and 39, respectively). The highest and lowest grain damage was recorded on cowpea samples collected from Dharwad (43.87 ± 2.01%) and Hiriyur (4.47 ± 1.19%), respectively. Under large scale storages, the highest and lowest grain damage was recorded on mungbean and cowpea samples collected from Vijayapura (13.69 ± 0.82 %) and Hiriyur (4.47 ± 1.19), respectively, whereas, under the small scale storages, the highest and lowest grain damage was found in cowpea samples collected from Dharwad (43.87 ± 2.01%) and Hunsur (4.95±1.07), respectively (Fig. 2b). Similar results of variable grain damage by bruchids have been observed also in the previous studies. Dias and Yadav (1998) in their survey recorded per cent seed damage of 14.65, 14.36, 10.08, 9.38 and 3.47 for redgram, cowpea, green pea, chickpea and black pea, respectively due to bruchid infestation. Goshal, T. K. (2003) found that the damage due to *C. chinensis* and *C. analis* was maximum on mungbean followed by urdbean, lentil, grass pea, cowpea, pigeonpea, chickpea and pea. In the present study, the bruchid damage varied between crops stored at different locations. The infestation and damage intensity were more related with grain moisture and duration of storage than the crops stored. In the present study, except for few locations, the grain damage was comparatively lesser (~ 4-12%) inspite of higher infestation, and this may be attributed to the timely prophylactic sprays (malathion and deltamethrin) and fumigation (AlPh3) activities.

Naveena *et al.* (2015) found that the number of food grain types stored by *Soligas* influenced species richness of stored insect species in a given locality. The diversity and distribution pattern of stored grain insects was influenced by anthropogenic factors (food grain sharing among *Soligas*, accessibility to the nearest towns and cities) rather than due to biotic and abiotic factors. Present study supports the same observation that the distribution of species is largely governed by the number of crops stored and anthropogenic movement of edible pulse grains through trade activities causing the distribution of three cosmopolitan species as evident in most parts of Karnataka including places where pulses were not commonly cultivated.

Egg Density Per Grain the egg density was varied significantly between twenty-three samples (H = 8.92, $P_{<0.05}$= 0.006, N = 69), however, it was not varied significantly between storage conditions (H = 0.71, $P_{<0.05}$= 0.44, n = 30 and 39, respectively). Interestingly, the crops with bold grain size received maximum egg density (chickpea, cowpea, pigeonpea, limabean and horsegram) when compared to crop with smaller grain size (mungbean, mothbean and urdbean). Overall, the grain samples collected from different locations recorded egg density per grain ranging between 1.11 ± 0.19 to 4.06 ± 0.54. Under large scale storages, the highest egg density was recorded on grains of lima bean (3.97 ± 0.36) from Yashwantpur, whereas, the lowest was recorded on urdbean (1.11 ± 0.19) from Gadag. Under small scale storages, the highest egg density was recorded from chickpea grains (4.06 ± 0.54) from Hiriyur and the lowest was on mothbean grains (1.18 ± 0.04) from Coorg (Fig. 2c).

Grain weight loss (%) : The grain weight loss was varied significantly between twenty-three grains samples (H=11.9, $P_{<0.01}$= 0.003, N = 69) as well as between storage conditions (H = 7.88, $P_{<0.05}$= 0004, n = 30 and 39, respectively), wherein, weight loss due to bruchid damage ranged between 10.10 ± 0.55 to 58.64 ± 6.05 per cent. The highest weight loss under large scale storage conditions was recorded in cowpea grains (58.64 ± 6.05) collected from Hiriyur, whereas,

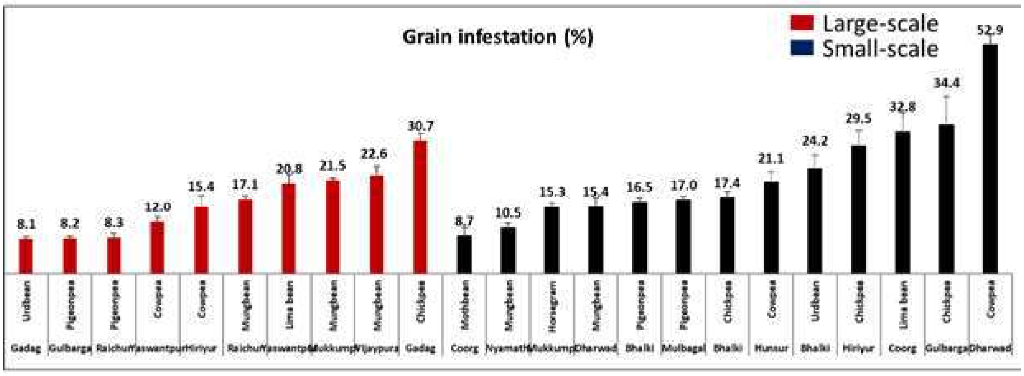

Fig. 2a : Mean (±SD) grain infestation (%) recorded on different grain samples collected from thirteen locations of Karnataka

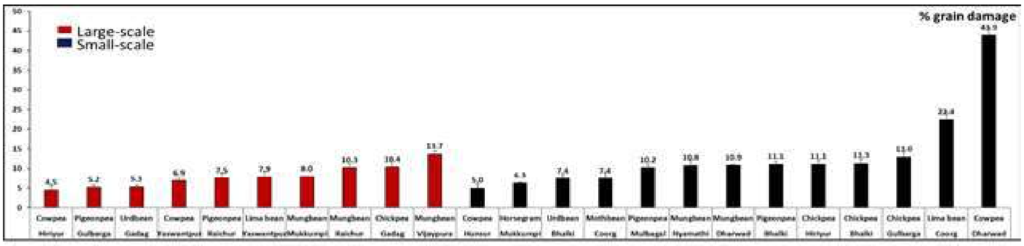

Fig. 2b: Mean (±SD) grain damage (%) due to bruchids recorded on different grain samples collected from thirteen locations of Karnataka

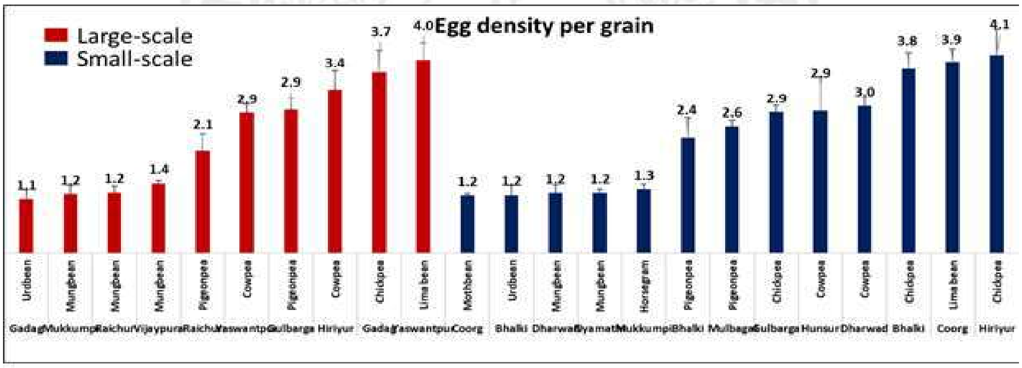

Fig. 2c : Mean (±SD) egg density per grain by bruchids recorded on different grain samples collected from thirteen locations of Karnataka

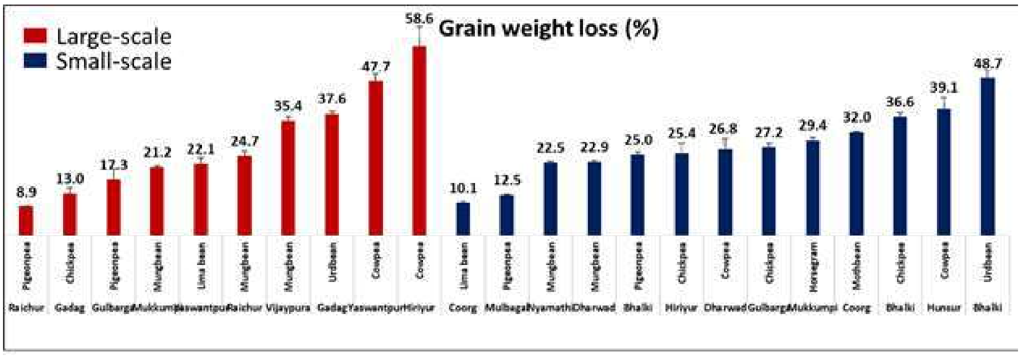

Fig. 2d: Mean (±SD) grain weight loss (%) due to bruchids damage recorded on different grain samples collected from thirteen locations of Karnataka

the lowest was recorded on pigeonpea (8.86 ± 0.12) collected from Raichur. In case of small scale storages, the highest weight loss was recorded on urdbean grains (48.74 ± 2.41) from Bhalki and lowest was on lima bean (10.10 ± 0.55) from Coorg. Gujar and Yadav (1978) recorded 50-60 per cent weight loss by *Callosobruchus maculates* when reared on different food at different temperatures. Ramzan *et al*. (1990) observed that the per cent damage of seeds due to *C. maculatus*as well as seed weight loss, respectively were found to be in descending order for cowpea (69.2% and 34.5%) > moth bean (53.7 and 21.9%) > green gram (50.3 and 19.4%). Silva and Costa (2016) observed the grain weight loss ranging between 0 - 7.07 per cent in cowpea due to *Callosobruchu s*sp. and 0 - 5.55 per cent due to *Zabrote* ssp. in common bean. In the present study, though there was lesser infestation percentage, the grain weight loss was comparatively higher, particularly in bold grain pulses. This can be attributed to the fact that the bold seeds received higher egg density resulting in many adults emerging from the single grain compared to the emergence of single adult in case of mungbean, mothbean and urdbean (Fig. 2d).

Diversity, Abundance and Dominance of Bruchid Species

A total of five species of bruchids were recorded from different stored pulse samples collected from all the locations. Three species were identified as *Callosobruchus chinensis* L., *C. maculatus* F. and *C. Analis* F. and two species were identified only up to genus level and are coded as *C.* Sp1 and *C.* Sp1 (table 1a & b). All the recorded species belonged to the subfamily Bruchinae (Chrysomelidae : Coleoptera). The maximum species diversity was recorded under small scale (H=0.56) storage conditions than the large scale (H=0.39) (Table 2). Among the five recorded species, *C. Analis* (54%) was more abundant under large scale storages followed by *C. chinensis* (37%). However, in case of small scale storages, *C. maculatus* (46%) was found to be more abundant followed by *C. Chinensis* (32%). Overall, *C. Chinensis* was recorded as the most abundant species across all locations followed by *C. analis, C. maculatus, C.* Sp1 and *C.* Sp2 (Fig. 3). With regard to the dominance of particular species, *C. analis* (d=0.54, 1/d=1.84) was found to be most dominant species under large scale storage conditions and *C. Maculates* (d=0.45, 1/

TABLE 2

Shannon-Weiner diversity (H) and Berger-parker dominance (d) indices for bruchid species collected from large and small scale storage conditions

		Large scale storage conditions				
Diversity index (H)	Dominance index (d)	*C. analis*	*C. chinensis*	*C. analis*	*Callosobruchus* Sp1	*Callosobruchus* Sp2
0.39	d	0.54	0.37	0.08	0.00	0.00
	1/d *	1.84	2.68	11.66	0.00	0.00
		Small scale storage conditions				
		C. analis	*C. chinensis*	*C. analis*	*Callosobruchus* Sp1	*Callosobruchus* Sp2
0.56	d	0.45	0.32	0.12	0.06	0.04
	1/d *	2.19	3.14	8.45	15.68	22.29

*Reciprocal of Berger-Parker dominance index indicating increase in abundance and decrease in dominance with the increase in1/d value

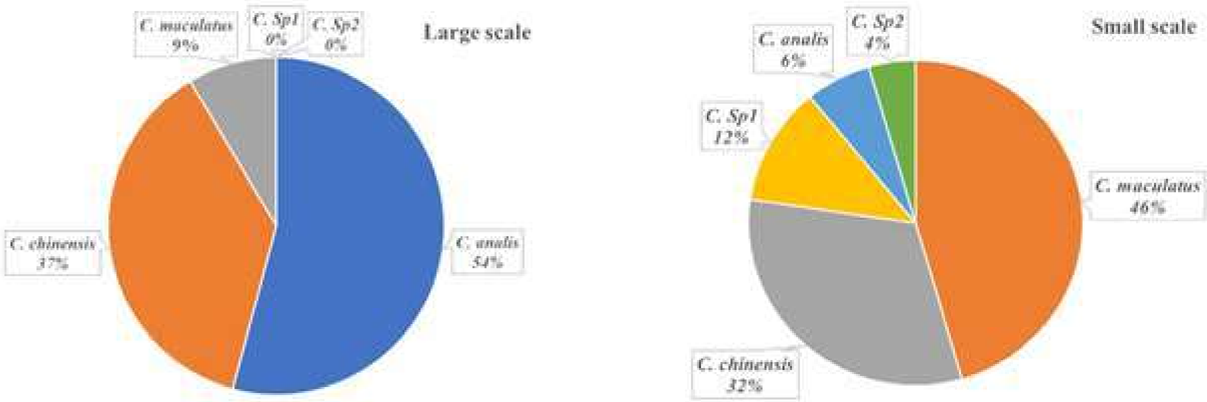

Fig. 3: relative abundance of different bruchid species under small and large scale storage conditions

d=2.19) in case of small scale storage conditions, (Table 2).

Similar to the present findings, Babrinde *et al.* (2016) performed a multistage sampling for stored cowpeas and identified three stored insect species *viz., Callosobruchus maculatus*, *Sitophilus zeamais* and *Tribolium castaneum*as common pests infesting stored grains. Bawa *et al.* (2017) studied the species diversity and abundance of *Callosobruchus* species infesting stored cowpea stocks collected from markets located in central regions of Ghana and reported five species *viz., Callosobruchus maculatus, C. rhodesianus, C. chinensis, C. analis* and *C. subinnotatus* infesting stored cowpea. Among these species *C. Maculates* was the most abundant and it outcompeted other species. Kingsolver *et al.* (2017) described a total of 43 bruchid species belonging to the family bruchidae that infests pulses. However, in the present study diversity of bruchids observed was relatively low and all the collected species were cosmopolitan ones.

Arora and Singal (1978) made extensive collections of bruchid species infesting wild legumes including pods of perennial trees between 1975-76 from different locations of southern India (Kerala, Tamil Nadu, Goa, Karnataka, Goa, Pondicherry). A total of 19 species of *Bruchidius* were recorded and seven species were reported to be new to the region. The present study reports the bruchid species infesting edible pulses only under stored conditions similar to the results of Dias and Yadav (1998) who noticed *C. maculatus, C analis, C theobromae* and *C pisorum* infesting

TABLE 3

Pearson's correlation between different parameters

	Quantity stored (kgs)	Storage duration (days)	Grain moisture (%)	Grain infestation (%)	Egg density / grain	Grain damage (%)	Weight loss (%)
Quantity stored (kgs)	1						
Storage duration (days)	-0.10	1					
Grain moisture (%)	-0.18	0.38	1				
Grain infestation (%)	-0.33	0.36	0.78 **	1			
Egg density/grain	0.20	0.09	0.34	0.39	1		
Grain damage (%)	-0.32	0.18	0.49 *	0.81 **	0.20	1	
Weight loss (%)	0.01	-0.27	-0.06	-0.11	-0.13	-0.22	1

**Significant @ 0.01, *Significant @0.05

six edible stored pulses across India. Among these species, *C. maculatus* was the dominant species followed by the *C. chinensis*, *C. analis, C. theobromae* and *C. pisorum.*. Pulse beetles have been reported as predominant stored pest infesting the stored lots of pulses in Karnataka (Kumar *et al*. 2005; Hampanna *et al*. (2006) .Naveena *et al*. (2015) identified 13 species of stored grain insect pests infesting stored grains of cereals and pulses in *Soliga* settlements across BR Hills, Karnataka. The bruchid species infesting stored pulses included *C. maculatus, C. chinensis, C. analis*and *C. theobromae.* Among all, *Sitophilous oryzae* and *Callosobruchus theobromae* were most abundant species. Harish *et al.* (2018) estimated the diversity and distribution of major stored pests and reported *C. analis, C. maaculatus, C. chinensis*and *T. casteneum* as key pests of stored pulses. *C. analis* was found to be dominant species followed by *C. chinensis* and *C. maculates* on stored pulse samples collected from Hyderabad-Karnataka region.

Gupta and Balla (2016) during quarantine processing of legume crops imported from over 40 countries between 1996-2015, intercepted 25 bruchid species belonging to the genus *Acenthosceloides, Bruchidius, Callosobruchus, Specularius, Bruchus* and *Zabrotes.* Of the 25 species, 13 species were not reported from India. The same team identified thirteen exotic bruchid species from the 2,819 imported legume samples during quarantine processing and the identified species included- *Acanthoscelidesdes manthi, A. obtectus, Bruchidius atrolineatus, Bruchus affinis, B. dentipes, B. ervi, B. nubilis, B. rufimanus, B. signaticornis, B. tristis, B. tristiculus, Callosobruchus rhodesianus* and *C. subinnotatus*. Both the studies highlighted the importance of quarantine in preventing entry of exotic stored pests to India. No invasive stored pests were identified in the present study.

Correlation Studies

The correlation studies indicated that the grain moisture played a significant role in infestation and grain damage as there was a significant positive correlation between grain moisture vs. infestation (r=0.78) and grain damage (0.49). Apart from this, the duration of grain storage positively influenced the infestation (0.36) and grain damage (0.18). The grain infestation (0.81) and egg density (0.2) were also found influencing the grain damage (Table 3).

The present study reports the diversity, distribution, abundance and dominance of bruchids infesting various edible stored pulses in the Karnataka state. It is further necessary to carryout extensive sampling to understand the bruchid species infesting stored pulses during different seasons of the year. Further, documentation on damage levels *vis a vis* management practices adopted, including the use of fumigant, Aluminium phosphide will throw up new insights about bruchid damage and their control.

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