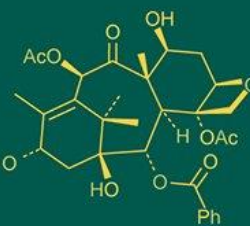
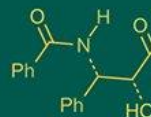
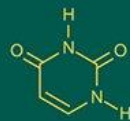
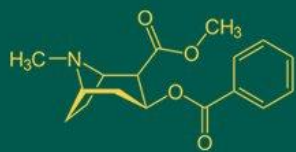


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Management of the pulse beetle, *Callosobruchus chinensis* (L.) in stored pigeonpea through botanicals and insecticides

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Abstract

Pigeonpea is one of the pulses most heavily damaged by the pulse beetle, *Callosobruchus chinensis* (L.) during storage, when left unchecked multiplication of the insect destroys both the consumable and seed value of the grain within a few months. The present investigation compared three edible oils (sunflower, oil palm and groundnut oil, each at 5 ml per kg of seed), three essential oils (neem, citronella and basil oil, each at 2.5 ml per kg) and three insecticidal molecules (spinosad 45 SC at 0.3 ml per kg, emamectin benzoate 5 SG at 0.4 g per kg and chlorantraniliprole 18.5 SC at 0.3 ml per kg) against an untreated control under ambient storage conditions for six months, in popular pigeonpea variety LRG-52 (Amaravathi). The observations that were monitored during the six month storage period are adult emergence, percentage of seeds bearing exit holes, per cent seed weight loss and germination per cent. The three edible oils together with the three insecticidal molecules achieved complete suppression of adult emergence, with no exit holes and zero weight loss for the entire storage period, while retaining acceptable germination (83.56 to 91.00 per cent). Neem oil at 2.5 ml per kg protected the seed only for the first two months before a sharp resurgence of the beetle, and its germination fell to 19.33 per cent by the sixth month. Citronella and basil oils neither stopped the occurrence of pest nor preserved seed quality, lowering mean germination to 34.33 and 39.00 per cent respectively, on par with the untreated control (37.44 per cent). The edible oils and the newer biomolecules are therefore recommended as safe, effective and farmer friendly protectants of stored pigeonpea seed for up to six months.

Keywords: Pigeonpea, *Callosobruchus chinensis*, edible oils, essential oils, insecticidal molecules, seed protectants, storage, germination

Introduction

Pigeonpea occupies a central place among Indian pulses, valued for its protein dense split dhal, its contribution to soil fertility through nitrogen fixation and its fit within rainfed cropping systems. A large share of the produce is held in farm and warehouse stores between harvest and the next sowing, and it is during this storage window that the crop suffers some of its heaviest losses. The pulse beetle, *Callosobruchus chinensis* (L.) (Coleoptera: Bruchidae), is the most destructive of the storage insects attacking the grain, with the grubs feeding internally on the cotyledons and the emerging adults boring characteristic exit holes through the seed coat. Repeated overlapping generations can reduce a stored lot to little more than frass and hollow seed coats, while the surviving seed loses weight, viability and germinability.

Conventional protection has long depended on synthetic fumigants and contact insecticides. Although effective, these chemicals carry well documented concerns over toxic residues, mammalian safety, environmental contamination and the steady build up of resistance in bruchid populations. Such drawbacks have renewed interest in protectants that are safer to handle, leave the treated seed fit for sowing and lend themselves to use by small farmers. Vegetable and essential oils have a long tradition in grain protection, acting as physical barriers that interfere with oviposition, egg respiration and larval establishment. Alongside them, a newer set of insecticidal molecules with novel modes of action, namely spinosad, emamectin benzoate and chlorantraniliprole, has shown promise as low dose, seed safe alternatives in stored pulses. Despite numerous studies evaluating edible oils, essential oils, and insecticidal insecticidal molecules for the management of pulse beetle, most comparisons have examined these treatment groups independently. Consequently, limited information is available on their relative effectiveness when assessed simultaneously under identical storage conditions.

Moreover, few studies have monitored both insect suppression and seed quality throughout an entire storage period using the same susceptible pigeonpea variety. Therefore, the present study was undertaken to compare the efficacy of edible oils, essential oils, and insecticidal insecticidal molecules against the pulse beetle in stored pigeonpea and to assess each treatment not only for its ability to suppress insect infestation but also for its influence on seed germinability during six months of ambient storage.

Materials and Methods

The storage experiment was carried out at the Department of

Seed Science and Technology, Advanced Post Graduate Centre, Lam, Guntur, under ambient laboratory conditions. Clean, freshly harvested seed of the popular pigeonpea variety LRG-52 (Amaravathi) served as the test material. Ten treatments, comprising nine protectants and an untreated control, were imposed in a completely randomised design with three replications. For each treatment 500gm of seed was thoroughly mixed with the protectant at the prescribed dose so that the seed was coated uniformly and shade dried, after which the seed was filled into identical containers of 1 kg capacity and held side by side throughout the trial. The treatments evaluated are listed below in Table 1.

Table 1: Various treatments used for the experiment

S. No	Treatment	Dose (ml or g/kg of seed)
T ₁	Sunflower oil	5.0
T ₂	Oil palm oil	5.0
T ₃	Groundnut oil	5.0
T ₄	Neem oil	2.5
T ₅	Citronella oil	2.5
T ₆	Basil oil	2.5
T ₇	Spinosad 45 SC	0.3
T ₈	Emamectin Benzoate 5 SG	0.4
T ₉	Chlorantraniliprole 18.5 SC	0.3
T ₁₀	Untreated control	—

Observations on the insect and on seed quality were recorded at monthly intervals over the six month storage period. The total number of adults that emerged was counted in every replication, and the number of seeds bearing exit holes was recorded and expressed in terms of percentage. Per cent seed weight loss was worked out and calculated based on the formula given by Adams and Sculten (1978) as a percentage. Germination was assessed by the standard germination test and reported as the percentage of normal seedlings produced. Before analysis of variance, the adult emergence data were transformed using the square root transformation, and the percentage data on exit holes and per cent seed weight loss were subjected to the arcsine (angular) transformation. The treatment means were compared using the critical difference (C.D.) at the 5 per cent level of significance, and the standard error of the mean (SE m) and coefficient of variation (C.V.) were computed for each observation period.

Results and Discussion

Total number of adults emerged: The treatments differed highly significantly in the number of adults that emerged at every monthly count (Table 2). Sunflower oil, oil palm oil and groundnut oil, each at 5 ml per kg, did not allow a single adult to emerge over the entire six months, recording a total and mean emergence of 0.00. The three insecticidal molecules, spinosad 45 SC, emamectin benzoate 5 SG and chlorantraniliprole 18.5 SC, were equally absolute in their action, with zero emergence throughout, marking these six treatments as the most effective protectants tested.

Neem oil at 2.5 ml per kg held the insect in check for the first two months, but the population rebounded thereafter, climbing from 15.67 adults in the third month to a peak of 617.33 in the fourth month before tapering to 245.00 in the fifth month, giving a total of 878.00 and a mean of 146.33. Among the susceptible treatments, citronella oil supported

the heaviest build up, with a mean emergence of 421.11 and a peak of 1206.00 adults in the fourth month, followed by basil oil (mean 344.56, peak 1007.33) and the untreated control (mean 407.28, peak 876.67). In every susceptible treatment the population dropped to nil by the sixth month, a fall that reflects the exhaustion of the available food rather than any protective effect. The very high coefficient of variation of 104.90 per cent for mean emergence captures the wide range between the fully protected and the unprotected treatments.

The complete shutdown of emergence under the three fixed vegetable oils is best explained by their physical mode of action. Unlike the volatile essential oils, these non volatile lipids spread as a continuous film over the seed coat that blocks egg attachment, disrupts the water balance of eggs already laid and seals the respiratory openings, so that developing embryos and newly hatched grubs are suffocated as the oil clogs their breathing pores. The result agrees closely with Khalequzzaman *et al.* (2007) ^[3], who recorded complete prevention of emergence with groundnut oil in stored pigeonpea, with Sreekanth *et al.* (2011) ^[10], who confirmed the value of sunflower oil in checking beetle multiplication, and with Bushra and Devi (2020) ^[2]. The rapid loss of efficacy under citronella and basil oils, in contrast, is tied to the high volatility of their terpenoid actives, which evaporate quickly at ambient temperature and leave behind no protective film at the low 2.5 ml per kg dose, a limitation also reported by Kumar *et al.* (2017) ^[4]. The delayed surge under neem oil, where the systemic limonoids deterred the beetle for two months before degrading, mirrors the behaviour of low botanical doses described by Bharadwaj and Verma (2012) ^[1]. The seed safe and highly effective performance of spinosad and emamectin benzoate is consistent with Mishra *et al.* (2018) ^[5] and Rathod *et al.* (2018) ^[8] in other stored pulses.

Table 2: Effect of botanicals and insecticidal molecules on adult emergence of pulse beetle, *C.chinensis*, over six months of storage in pigeonpea

S. No	Treatment (concentration/kg of seed)	No. of adults emerged						Total	Mean
		After 1st month	After 2nd month	After 3rd month	After 4th month	After 5th month	After 6th month		
1	Sunflower oil @ 5 ml/kg	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00	0.00 (1.00)
2	Oil palm oil @ 5 ml/kg	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00	0.00 (1.00)
3	Groundnut oil @ 5 ml/kg	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00	0.00 (1.00)
4	Neem oil @ 2.5 ml/kg	0.00 (1.00)	0.00 (1.00)	15.67 (4.06)	617.33 (24.83)	245 (15.64)	0.00 (1.00)	878.00	146.33 (7.94)
5	Citronella oil @ 2.5 ml/kg	120.33 (11.01)	344.67 (18.59)	566.67 (23.74)	1206 (34.43)	289 (17.00)	0.00 (1.00)	2526.67	421.11 (17.70)
6	Basil oil @ 2.5 ml/kg	60.67 (7.64)	340.67 (18.48)	476.67 (21.83)	1007.33 (31.44)	182 (13.50)	0.00 (1.00)	2067.34	344.56 (15.75)
7	Spinosad 45 SC @ 0.3 ml/kg	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00	0.00 (1.00)
8	Emamectin benzoate 5 SG @ 0.4 g/kg	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00	0.00 (1.00)
9	Chlorantraniliprole 18.5 SC @ 0.3 ml/kg	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00	0.00 (1.00)
10	Untreated control	118.67 (10.87)	433.33 (20.82)	770 (27.75)	876.67 (29.57)	245 (15.64)	0.00 (1.00)	2443.67	407.28 (17.64)
	C.D. (5%)	1.46	0.68	1.60	4.56	1.35	—	—	7.93
	SE (m)	0.49	0.23	0.54	1.53	0.46	—	—	2.79
	SE(d)	0.69	0.32	0.76	2.17	0.64	—	—	3.94
	C.V. (%)	23.28	6.11	11.16	21.04	11.63	—	—	104.90

Adult emergence data were subjected to square root transformation prior to analysis

Per cent seeds bearing exit holes

The proportion of seeds carrying exit holes, the visible mark of adult escape, followed the emergence pattern closely (Fig 1). The three edible oils and the three insecticidal molecules kept the seed entirely free of exit holes through all six months, a direct consequence of the complete absence of adult emergence in these treatments. Neem oil held at zero for two months, then damage appeared from the third month onwards, rising through 24.71 and 30.68 per cent to 65.79 per cent in the fifth month and 67.96 per cent in the sixth, tracking the resurgence of the beetle in this treatment.

Citronella oil, basil oil and the untreated control showed perforation from the very first month and climbed steeply thereafter. Citronella oil rose from 6.29 per cent to 93.61 per cent, basil oil from 2.62 per cent to 91.38 per cent and the control from 10.58 per cent to 91.64 per cent by the sixth month. The high coefficient of variation in the early months, 168.20 per cent in the first month, simply reflects the fact that most treatments recorded no damage at that stage while a few began to deteriorate. The strict correspondence between exit holes and adult emergence, and the complete suppression of both by the edible oils and insecticidal molecules, is in line with Sharma *et al.* (2016) [9], who reported that neem oil at a higher dose of 10 ml per kg fully prevented seed damage in stored pigeonpea. The breakdown of protection under neem oil at 2.5 ml per kg suggests that a higher concentration is

needed for season long protection.

Per cent seed weight loss

Seed weight loss, the practical measure of grain depletion, again separated the treatments sharply (Table 3). The three edible oils and the three insecticidal molecules kept the seed weight wholly intact, recording nil loss across all six months and standing statistically superior to the rest, a direct outcome of the complete prevention of beetle development since weight loss in stored pulses stems mainly from internal larval feeding and adult exit. Citronella oil carried the highest loss, beginning at 0.97 per cent and rising steadily to 37.62 per cent by the sixth month, followed closely by basil oil (0.41 to 35.75 per cent) and the untreated control (2.13 to 36.51 per cent). By the later months the loss under citronella and basil oils approached or exceeded that of the control, underlining how poorly these essential oils performed at 2.5 ml per kg. Neem oil held the weight intact for the first two months and then lost ground gradually, reaching 23.76 per cent by the sixth month, yet remained well below the citronella and basil treatments. The minimal weight loss under the edible oils corroborates Khalequzzaman *et al.* (2007) [3] and Srinivasan (2008) [11], while the negligible loss under spinosad and emamectin benzoate agrees with Rashmi *et al.* (2014) [7] and Vishwamitra *et al.* (2014) [13]. The heavy loss under basil oil is in conformity with Kumar *et al.* (2017) [4].

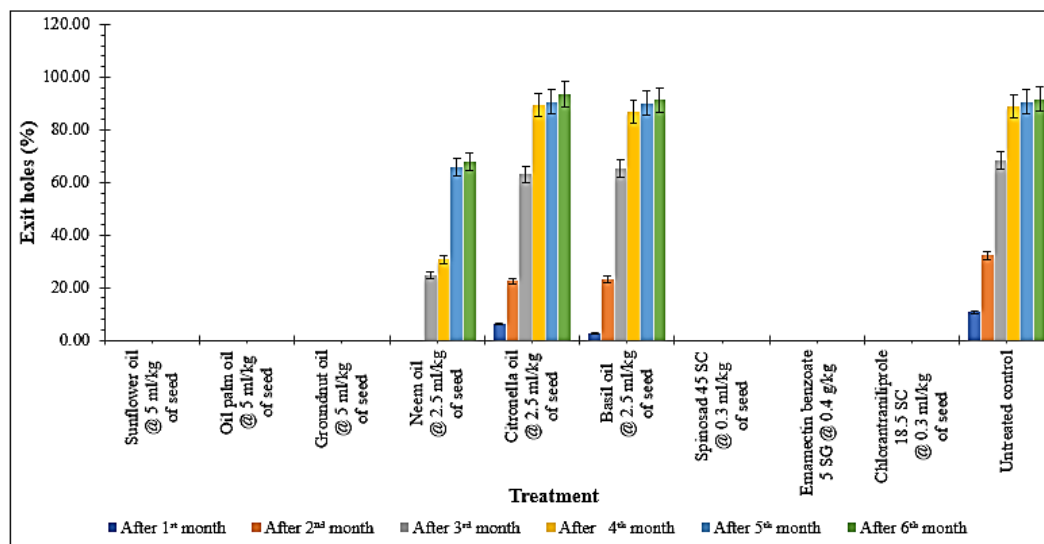


Fig 1: Percentage of seeds with exit holes over six months storage period treated with different botanicals and insecticides in pigeonpea against pulse beetle, *C. chinensis*

Table 3: Influence of botanicals and insecticidal molecules on per cent seed weight loss over six months of storage in pigeonpea

S. No	Treatment	Weight loss (%)					
		After 1st month	After 2nd month	After 3rd month	After 4th month	After 5th month	After 6th month
1	Sunflower oil @ 5 ml/kg of seed	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
2	Oil palm oil @ 5 ml/kg of seed	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
3	Groundnut oil @ 5 ml/kg of seed	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
4	Neem oil @ 2.5 ml/kg of seed	0.00 (0.00)	0.00 (0.00)	4.36 (11.86)	7.10 (14.71)	17.01 (24.32)	23.76 (29.13)
5	Citronella oil @ 2.5 ml/kg of seed	0.97 (5.08)	8.19 (15.64)	19.40 (26.06)	26.94 (31.22)	28.53 (32.23)	37.62 (37.82)
6	Basil oil @ 2.5 ml/kg of seed	0.41 (3.66)	2.81 (9.50)	12.45 (20.30)	21.05 (27.29)	24.82 (29.86)	35.75 (36.71)
7	Spinosad 45 SC @ 0.3 ml/kg of seed	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
8	Emamectin benzoate 5 SG @ 0.4 g/kg of seed	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
9	Chlorantraniliprole 18.5 SC @ 0.3 ml/kg of seed	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
10	Untreated control	2.13 (7.82)	8.81 (17.03)	16.87 (24.23)	21.17 (27.38)	25.20 (30.10)	36.51 (37.15)
	C.D.(5%)	2.64	4.55	3.46	3.64	1.94	1.50
	SE(m)	0.89	1.53	1.16	1.23	0.65	0.50
	SE(d)	1.26	2.17	1.65	1.74	0.92	0.71
	C.V. (%)	92.92	62.93	24.46	21.12	9.72	6.20

Percentage data were subjected to arcsine transformation prior to analysis

Per cent germination

Because the protected seed is meant for sowing, its germinability is the ultimate test of any treatment (Fig 2). Chlorantraniliprole 18.5 SC gave the highest mean germination of 91.00 per cent, closely followed by spinosad 45 SC (89.33 per cent), sunflower oil (89.00 per cent) and emamectin benzoate 5 SG (87.67 per cent), all of which sustained high viability throughout storage. Oil palm oil (86.11 per cent) and groundnut oil (83.56 per cent) also kept germination within an acceptable range, confirming that the edible oils at 5 ml per kg were broadly safe for seed. Neem oil, by contrast, showed a steep decline from 86.67 per cent in the first month to just 19.33 per cent in the sixth, with a mean of only 60.33 per cent, the fall coinciding with the resurgent beetle damage and the effect of the oil itself at 2.5

ml per kg. Citronella and basil oils were the most damaging to seed quality, mean germination dropping to 34.33 and 39.00 per cent respectively, no better than the untreated control at 37.44 per cent. The drastic decline in germination was likely due to the combined effects of phytotoxicity at the applied dose and inadequate inhibition of larval feeding by the essential oils, resulting in irreversible embryo damage. The preservation of viability by the edible oils and insecticidal molecules accords with Khalequzzaman *et al.* (2007) [3], Raghvani and Kapadia (2003) [6], Bushra and Devi (2020) [2], Mishra *et al.* (2018) [5], Rathod *et al.* (2018) [8] and Thirumala Raju and Jyothi (2016) [12], whereas the poor germination under citronella and basil oils parallels the inferior protection reported by Kumar *et al.* (2017) [4].

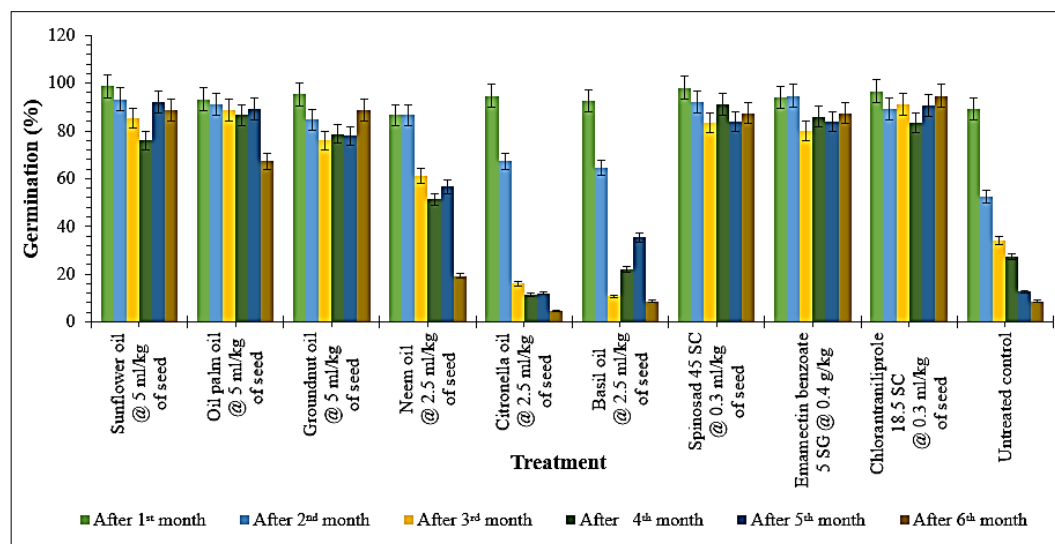


Fig 2: Influence of botanicals and insecticides on germination per cent of pigeonpea seeds during six months of storage

Conclusion

Sunflower, oil palm and groundnut oils at 5 ml per kg and the three insecticidal molecules, spinosad 45 SC, emamectin benzoate 5 SG and chlorantraniliprole 18.5 SC, gave complete and durable protection to stored pigeonpea, holding adult emergence, exit holes and weight loss at nil for the full six months while keeping germination at safe and acceptable levels (83.56 to 91.00 per cent). Neem oil at 2.5 ml per kg protected the seed only for two months before the beetle rebounded and germination fell to 19.33 per cent, making it unsuitable for long storage at this dose. Citronella and basil oils at 2.5 ml per kg neither managed the pest nor preserved viability, leaving germination as low as the untreated control. The edible oils and the newer insecticidal molecules are therefore recommended as effective, seed safe and farmer friendly protectants for the management of *Callosobruchus chinensis* in stored pigeonpea for periods of up to six months.

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