# Evaluation of Some Plant Products against *Trogoderma granarium* Everts in Stored Maize and Their Effects on Nutritional Composition and Organoleptic Characteristics of Kernels

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Neem (*Azadirachta indica*) oil and powders of neem leaf and neem kernel, citrus (*Citrus limon*) leaf, garlic (*Allium sativum*) bulb, and podina (*Mentha spicata*) leaf were used in maize kernels at 1 and 2% level (w/w) against larvae of *Trogoderma granarium* Everts. Neem kernel powder and oil provided complete protection to grains for 6 months, whereas substantial insect infestations (7–19%) were noticed after 3 months in other treatments. Infestation increased progressively and reached as high as 35 (neem leaf and podina), 43 (citrus), and 62% (garlic) after 6 months. Moisture, ash, fiber, fat, protein, and carbohydrates of treated kernels remained unaffected after 1 month of storage. After 6 months, changes in nutritional composition were proportional to insect damage. Chapatis (unleavened bread) prepared from flour of treated kernels after 1 and 6 months were of normal color, appearance, and texture, but their taste, aroma, and overall acceptability were adversely affected by insect infestation, plant products, or their combination.

## INTRODUCTION

Maize is a valuable source of protein, carbohydrates, B vitamins, and some minerals. It is mainly consumed in the form of chapatis (unleavened bread) made from kernel flour in rural communities of Asia and Africa. Maize kernels are attacked by a large number of insects during storage. *Trogoderma granarium* Everts is among the most serious and of widest occurrence of insect pests in stored grains in tropical and subtropical regions of Asia and Africa (Atwal, 1976; Salunkhe *et al.*, 1985; Viljoen, 1990). Larval feeding in maize kernels has been found to adversely affect quality of minerals (Jood *et al.*, 1992a), available carbohydrates (Jood *et al.*, 1993), protein and starch digestibility (Jood and Kapoor, 1992), and bioavailability of proteins (Jood *et al.*, 1992b).

Plant origin products are receiving greater attention as prophylactic measures against stored product pests, mainly because of their safety to nontarget organisms. Neem (*Azadirachta indica*) products including leaf, kernel, and seed powders, seed extracts, and oil have been reported as effective protectants against several stored product pests (Girish and Jain, 1974; Singh and Srivastava, 1980; Ivbijaro, 1983; Tanjubil, 1986; Saxena, 1989; Schmutterer, 1990). Likewise, citrus (*Citrus limon*) leaf powder (Golob and Webley, 1980), podina (*Mentha spicata*) leaf powder (Kashyap *et al.*, 1974), and garlic (*Allium sativum*) bulb powder (Sowunmi and Akinnusi, 1983) were also found to be promising grain protectants against some storage pests. However, information is lacking on the effect of these formulations on the nutritional composition and organoleptic characteristics of treated grains. Hence, the purpose of this study was to test the efficacy and persistence of four readily available plant products, including neem leaf powder, kernel powder, and oil, podina leaf powder, citrus leaf powder, and garlic bulb powder, against larvae of *T. granarium* and their effects on nutritional composition and organoleptic characteristics of treated kernels.

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## MATERIALS AND METHODS

**Preparation of Grain Samples.** The kernels of a commonly consumed cultivar of maize (Composite Vijay), believed to be free from insect infestation, were procured and subjected to aluminum phosphide fumigation to eliminate any untraced insects. After fumigation, the grains were put in 78 glass jars, each containing 750 g of grains. The jars were covered with muslin cloth secured with elastic bands and placed in the laboratory for 10 days for conditioning of kernels. On the 10th day, the moisture level of grains ranged from 10 to 11%, which is suitable for feeding of *T. granarium* (Pingale and Girish, 1967). The culture of *T. granarium* was maintained in the laboratory at an ambient temperature between 28 and 39 °C and relative humidity between 60 and 90% (Jood, 1990).

**Preparation of Plant Samples.** Neem leaves, neem kernels, garlic bulbs, podina leaves, and citrus leaves were procured from the research farm, Haryana Agricultural University, Hisar. These were shade-dried and ground to a fine powder before passing through a 40-mesh sieve. Neem oil was procured from a local market. These products were mixed with the maize kernels at 1 and 2% levels (w/w).

**Efficacy and Persistence.** A total of 78 jars containing maize kernels were divided into 4 groups. In the first group of 36 jars, desired amounts of six plant products at 1 and 2% concentration were added to grains. Each treatment was replicated three times. The jars were shaken vigorously to mix the products uniformly in the kernels. After the plant extracts were mixed, 30 larvae were released in each jar. The efficacy and persistence of plant products were evaluated by recording kernel damage at monthly intervals up to 6 months. At each observation, 500 kernels from each jar were inspected; the kernels that showed signs of insect damage were considered to be infested. Infestation level was calculated by dividing the number of insect-damaged kernels by the number of total kernels inspected and then multiplied by 100.

To determine if plant products affected the nutritional composition and organoleptic characteristics of the kernels 1 month after treatment, a second group of 36 jars containing plant products were mixed as described above but insects were not added to the kernels. In the third group of three jars, kernels received insects only, while in the fourth group (three jars), kernels were kept free from insects as well as plant products to compare these results with the other treatments.

**Effect on Nutritional Composition.** Plant product treated (insect free) samples were passed through a 40-mesh sieve to

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**Table I. Bioefficacy and Persistence of Some Plant Protectants against *T. granarium* in Maize Stored for 6 Months[a]**

| treatment | concn, % (w/w) | kernel infestation, %, after storage for 1 month | 2 months | 3 months | 4 months | 5 months | 6 months | weight loss, % |
|---|---|---|---|---|---|---|---|---|
| citrus leaf powder | 1 | 2 (9.10) | 5 (13.56) | 8 (16.95) | 19 (26.21) | 25 (30.33) | 43 (41.27) | 3.9 (12.11) |
| | 2 | 1 (7.04) | 4 (12.25) | 8 (16.95) | 18 (25.48) | 24 (29.67) | 40 (39.52) | 3.5 (11.54) |
| | mean | 1.5 (8.13) | 4.5 (12.92) | 8.0 (16.95) | 18.5 (25.84) | 24.5 (30.00) | 41.5 (40.40) | 3.7 (11.83) |
| garlic powder | 1 | 3 (10.78) | 7 (15.89) | 19 (26.21) | 23 (29.00) | 42 (40.69) | 62 (52.24) | 5.5 (14.18) |
| | 2 | 1 (7.04) | 6 (14.77) | 12 (20.70) | 20 (26.92) | 40 (39.52) | 55 (48.16) | 5.0 (13.56) |
| | mean | 2.0 (9.10) | 6.5 (15.34) | 15.5 (23.58) | 21.5 (27.97) | 41.0 (40.11) | 58.5 (49.89) | 5.2 (13.81) |
| podina leaf powder | 1 | 2 (9.10) | 4 (12.25) | 8 (16.95) | 11 (19.82) | 25 (30.33) | 35 (36.57) | 3.4 (11.39) |
| | 2 | 1 (7.04) | 4 (12.25) | 8 (16.95) | 18 (25.48) | 28 (32.27) | 35 (36.57) | 3.4 (11.39) |
| | mean | 1.5 (8.13) | 4.0 (12.25) | 8.0 (16.95) | 14.5 (22.79) | 26.5 (31.31) | 35.0 (36.57) | 3.4 (11.39) |
| neem leaf powder | 1 | 2 (9.10) | 4 (12.25) | 8 (16.95) | 18 (25.48) | 28 (32.27) | 35 (36.57) | 3.4 (11.39) |
| | 2 | 0 (4.05) | 3 (10.78) | 7 (15.89) | 15 (23.19) | 25 (30.33) | 30 (33.52) | 3.1 (10.94) |
| | mean | 1.0 (7.04) | 3.5 (11.54) | 7.5 (16.43) | 16.5 (24.35) | 26.5 (31.31) | 32.5 (35.06) | 3.2 (11.09) |
| neem kernel powder | 1 | 0 (4.05) | 0 (4.05) | 0 (4.05) | 0 (4.05) | 0 (4.05) | 0 (4.05) | 0 (4.05) |
| | 2 | 0 (4.05) | 0 (4.05) | 0 (4.05) | 0 (4.05) | 0 (4.05) | 0 (4.05) | 0 (4.05) |
| | mean | 0 (4.05) | 0 (4.05) | 0 (4.05) | 0 (4.05) | 0 (4.05) | 0 (4.05) | 0 (4.05) |
| neem oil | 1 | 0 (4.05) | 0 (4.05) | 0 (4.05) | 0 (4.05) | 0 (4.05) | 0 (4.05) | 0 (4.05) |
| | 2 | 0 (4.05) | 0 (4.05) | 0 (4.05) | 0 (4.05) | 0 (4.05) | 0 (4.05) | 0 (4.05) |
| | mean | 0 (4.05) | 0 (4.05) | 0 (4.05) | 0 (4.05) | 0 (4.05) | 0 (4.05) | 0 (4.05) |
| control (untreated) | | 20 (26.92) | 42 (40.69) | 50 (45.29) | 58 (55.86) | 76 (61.00) | 83 (66.03) | 10.2 (19.09) |
| treatment | SE ($m$) | (0.55) | (0.77) | (0.74) | (1.09) | (1.19) | (1.19) | (0.55) |
| | CD ($P < 0.05$) | (1.63) | (2.27) | (2.22) | (3.29) | (3.55) | (3.55) | (1.60) |
| concn | SE ($m$) | (0.31) | (0.44) | (0.43) | (0.63) | (0.69) | (0.68) | (0.31) |
| | CD ($P < 0.05$) | (0.93) | (NS)[b] | (NS) | (NS) | (NS) | (1.94) | (NS) |
| treatment × concn | SE ($m$) | (0.77) | (1.09) | (1.05) | (1.54) | (1.69) | (1.68) | (0.78) |
| | CD ($P < 0.05$) | (2.31) | (NS) | (NS) | (NS) | (NS) | (NS) | (NS) |

[a] Figures in parentheses are angular transformation. [b] Not significant.

**Table II. Effect of Some Plant Protectants on Proximate Composition of Maize after 1 Month of Storage (Grams per 100 g, Dry Matter Basis)[a]**

| treatment | concn, % | moisture | ash | crude fiber | crude fat | total protein | total carbohydrates |
|---|---|---|---|---|---|---|---|
| citrus leaf powder | 1 | 11.09 ± 0.12 | 1.50 ± 0.01 | 2.22 ± 0.01 | 3.30 ± 0.02 | 11.40 ± 0.14 | 70.49 ± 0.61 |
| | 2 | 11.12 ± 0.11 | 1.54 ± 0.02 | 2.21 ± 0.03 | 3.31 ± 0.03 | 11.48 ± 0.13 | 70.34 ± 0.52 |
| garlic powder | 1 | 11.26 ± 0.12 | 1.55 ± 0.01 | 2.18 ± 0.01 | 3.29 ± 0.01 | 11.38 ± 0.13 | 70.34 ± 0.56 |
| | 2 | 11.18 ± 0.12 | 1.58 ± 0.02 | 2.21 ± 0.01 | 3.32 ± 0.01 | 11.49 ± 0.11 | 70.22 ± 0.62 |
| podina leaf powder | 1 | 11.23 ± 0.11 | 1.55 ± 0.01 | 2.22 ± 0.02 | 3.30 ± 0.02 | 11.45 ± 0.12 | 70.25 ± 0.53 |
| | 2 | 11.04 ± 0.12 | 1.52 ± 0.01 | 2.19 ± 0.01 | 3.29 ± 0.01 | 11.49 ± 0.12 | 70.47 ± 0.44 |
| neem leaf powder | 1 | 11.20 ± 0.11 | 1.55 ± 0.02 | 2.21 ± 0.02 | 3.29 ± 0.02 | 11.48 ± 0.13 | 70.27 ± 0.32 |
| | 2 | 11.14 ± 0.12 | 1.56 ± 0.01 | 2.22 ± 0.01 | 3.30 ± 0.01 | 11.46 ± 0.13 | 70.32 ± 0.46 |
| neem kernel powder | 1 | 11.03 ± 0.13 | 1.50 ± 0.01 | 2.20 ± 0.01 | 3.32 ± 0.02 | 11.50 ± 0.14 | 70.45 ± 0.52 |
| | 2 | 11.24 ± 0.12 | 1.53 ± 0.01 | 2.22 ± 0.01 | 3.36 ± 0.01 | 11.49 ± 0.13 | 70.16 ± 0.53 |
| neem oil | 1 | 11.06 ± 0.11 | 1.55 ± 0.01 | 2.21 ± 0.02 | 3.46 ± 0.02 | 11.46 ± 0.12 | 70.26 ± 0.54 |
| | 2 | 11.08 ± 0.12 | 1.55 ± 0.01 | 2.20 ± 0.01 | 3.60 ± 0.02 | 11.48 ± 0.12 | 70.09 ± 0.58 |
| control (uninfested) | 0 | 11.00 ± 0.13 | 1.55 ± 0.01 | 2.21 ± 0.01 | 3.30 ± 0.01 | 11.48 ± 0.12 | 70.46 ± 0.62 |
| treatment | SE ($m$) | 0.20 | 0.04 | 0.02 | 0.11 | 0.09 | 0.52 |
| | CD ($P < 0.05$) | NS[b] | NS | NS | NS | NS | NS |
| concn | SE ($m$) | 0.21 | 0.05 | 0.02 | 0.05 | 0.08 | 0.51 |
| | CD ($P < 0.05$) | NS | NS | NS | NS | NS | NS |
| treatment × concn | SE ($m$) | 0.32 | 0.08 | 0.04 | 0.21 | 0.16 | 1.10 |
| | CD ($P < 0.05$) | NS | NS | NS | NS | NS | NS |

[a] Values are means ± SD of six independent determinations. [b] Not significant.

remove plant products after 1 month of treatment. These kernels were analyzed for moisture, ash, total protein, crude fat, total carbohydrates, and crude fiber by employing the standard methods of analysis (AOAC, 1980). A factor of 6.25 was applied to convert nitrogen to total protein. Similarly, kernels that received insect populations were fumigated with aluminum phosphide after 6 months of treatment to kill insects. These were passed over a 4-mesh sieve to remove the dead insects, frass, and plant products. Weight loss in kernels was also estimated (Jood, 1990). The cleaned kernels were analyzed for nutritional composition and compared with control samples (free from insects and plant products).

**Organoleptic Evaluation.** Chapatis were used to evaluate the organoleptic characteristics of flours made from kernels subjected to various treatments as described above. The chapatis were evaluated for color, taste, texture, aroma, appearance, and overall acceptability by a nine-point hedonic scale ranging from very desirable to very undesirable (Austin and Ram, 1971). Chapatis were scored for each character by a panel of 10 judges.

**Statistical Analysis.** The data were subjected to analysis of variance (ANOVA) in a completely randomized design to determine critical difference (CD) among treatments. The difference of two means between/within treatments exceeding CD value is significant (Panse and Sukhatme, 1978). Data on kernel infestation and weight loss were transformed to angular values. Chemical composition and organoleptic characteristic values were used to calculate standard deviations (SD) (Snedecor and Cochran, 1968).

## RESULTS AND DISCUSSION

**Efficacy and Persistence.** All six plant products (Table I) at 1 and 2% levels proved to be superior for control for 6 months. Neem kernel powder and neem oil provided complete protection against insect infestation for 6 months, whereas in other treatments it was insignificant up to 3 months. After 4 months, a significant increase in infestation of kernels mixed with citrus leaf powder (18.5%), garlic powder (21.5%), podina leaf powder (14.5%), and neem leaf powder (16.5%) was noticed. Thereafter, infestation levels were beyond acceptable

**Table III. Effect of *T. granarium* Infestation on Proximate Composition of Maize Treated with Some Plant Protectants after 6 Months of Storage (Grams per 100 g, Dry Matter Basis)[a,b]**

| treatment | concn, % | infestation level, % | moisture | ash | crude fiber | crude fat | total protein | total carbohydrates |
|---|---|---|---|---|---|---|---|---|
| citrus leaf powder | 1 | 43 | 12.24 ± 0.11 (+5) | 1.53 ± 0.02 (−1) | 2.42 ± 0.04 (+7) | 3.05 ± 0.05 (−5) | 14.90 ± 0.12 (+19) | 65.86 ± 0.46 (−4) |
| | 2 | 40 | 11.99 ± 0.09 (+3) | 1.53 ± 0.01 (−1) | 2.39 ± 0.02 (+6) | 3.09 ± 0.02 (−3) | 14.85 ± 0.09 (+19) | 66.15 ± 0.32 (−4) |
| | mean | 41.50 | 12.11 | 1.53 | 2.41 | 3.07 | 14.87 | 66.01 |
| garlic powder | 1 | 62 | 12.98 ± 0.06 (+11) | 1.50 ± 0.02 (−3) | 2.51 ± 0.03 (+11) | 2.95 ± 0.03 (−8) | 17.10 ± 0.14 (+37) | 62.96 ± 0.28 (−9) |
| | 2 | 55 | 12.50 ± 0.10 (+7) | 1.52 ± 0.03 (−2) | 2.46 ± 0.02 (+9) | 3.00 ± 0.03 (−6) | 16.95 ± 0.15 (+36) | 63.57 ± 0.29 (−8) |
| | mean | 58.50 | 12.74 | 1.51 | 2.49 | 3.01 | 17.02 | 63.26 |
| podina leaf powder | 1 | 40 | 11.91 ± 0.08 (+3) | 1.53 ± 0.01 (−1) | 2.39 ± 0.02 (+6) | 3.09 ± 0.02 (−3) | 14.85 ± 0.12 (+19) | 66.15 ± 0.32 (−4) |
| | 2 | 35 | 11.82 ± 0.11 (+1) | 1.55 ± 0.02 (0) | 2.33 ± 0.01 (+3) | 3.14 ± 0.04 (−2) | 14.80 ± 0.13 (+18) | 66.36 ± 0.36 (−4) |
| | mean | 37.50 | 11.86 | 1.54 | 2.36 | 3.11 | 14.83 | 66.25 |
| neem leaf powder | 1 | 35 | 12.00 ± 0.12 (+4) | 1.54 ± 0.01 (−0.6) | 2.33 ± 0.03 (+3) | 3.14 ± 0.03 (−2) | 14.81 ± 0.09 (+18) | 66.08 ± 0.35 (−4) |
| | 2 | 30 | 11.93 ± 0.13 (+2) | 1.55 ± 0.02 (0) | 2.30 ± 0.01 (+2) | 3.16 ± 0.02 (−1) | 14.77 ± 0.10 (+18) | 66.29 ± 0.24 (−4) |
| | mean | 32.50 | 12.01 | 1.55 | 2.32 | 3.15 | 14.74 | 66.19 |
| neem kernel powder | 1 | 0 | 11.69 ± 0.08 (+0.2) | 1.54 ± 0.01 (−0.6) | 2.27 ± 0.02 (+0.4) | 3.22 ± 0.03 (+0.6) | 12.54 ± 0.09 (+0.3) | 68.74 ± 0.39 (−0.1) |
| | 2 | 0 | 11.68 ± 0.09 (+0.1) | 1.55 ± 0.02 (0) | 2.28 ± 0.01 (+0.9) | 3.24 ± 0.04 (−1) | 12.56 ± 0.08 (+0.5) | 68.69 ± 0.42 (−0.2) |
| | mean | 0 | 11.69 | 1.55 | 2.28 | 3.23 | 12.55 | 68.72 |
| neem oil | 1 | 0 | 11.67 ± 0.04 (0) | 1.54 ± 0.01 (−0.6) | 2.27 ± 0.02 (+0.4) | 3.30 ± 0.03 (+3) | 12.53 ± 0.10 (+0.2) | 68.69 ± 0.21 (−0.2) |
| | 2 | 0 | 11.64 ± 0.06 (−0.3) | 1.55 ± 0.01 (0) | 2.26 ± 0.01 (0) | 3.35 ± 0.02 (+5) | 12.54 ± 0.12 (+0.3) | 68.66 ± 0.18 (−0.2) |
| | mean | 0 | 11.65 | 1.55 | 2.26 | 3.22 | 12.54 | 68.68 |
| control (uninfested) | | 0 | 11.67 ± 0.12 | 1.55 ± 0.01 | 2.26 ± 0.02 | 3.20 ± 0.02 | 12.50 ± 0.12 | 68.82 ± 0.28 |
| treatment | SE (*m*) | | 0.25 | 0.09 | 0.06 | 0.04 | 0.15 | 0.49 |
| | CD ($P <$ 0.05) | | 0.72 | NS[c] | 0.18 | 0.12 | 0.45 | 1.45 |
| concn | SE (*m*) | | 0.21 | 0.07 | 0.07 | 0.03 | 0.11 | 0.50 |
| | CD ($P <$ 0.05) | | NS | NS | NS | NS | NS | NS |
| treatment × concn | SE (*m*) | | 0.38 | 0.10 | 0.12 | 0.07 | 0.29 | 0.75 |
| | CD ($P <$ 0.05) | | NS | NS | NS | NS | NS | NS |

[a] Values are means ± SD of six independent determinations. [b] Figures in parentheses are percent change over control. [c] Not significant.

**Table IV. Effect of Some Plant Protectants on Organoleptic Characteristics of Maize Chapatis after 1 Month of Storage (Values Are ±SD of Mean Scores of 10 Panelists)**

| treatment | concn, % | color | appearance | aroma | texture | taste | overall acceptability score |
|---|---|---|---|---|---|---|---|
| citrus leaf powder | 1 | 7.4 ± 0.2 | 7.5 ± 0.3 | 7.5 ± 0.2 | 7.1 ± 0.2 | 7.0 ± 0.4 | 7.3 ± 0.3 |
| | 2 | 7.5 ± 0.3 | 7.4 ± 0.2 | 7.4 ± 0.3 | 7.1 ± 0.3 | 6.9 ± 0.3 | 7.3 ± 0.3 |
| garlic powder | 1 | 7.5 ± 0.2 | 7.5 ± 0.3 | 6.6 ± 0.2 | 7.2 ± 0.2 | 5.3 ± 0.3 | 6.8 ± 0.2 |
| | 2 | 7.4 ± 0.1 | 7.4 ± 0.2 | 6.4 ± 0.3 | 7.0 ± 0.3 | 4.8 ± 0.2 | 6.6 ± 0.2 |
| podina leaf powder | 1 | 7.3 ± 0.3 | 7.5 ± 0.1 | 7.4 ± 0.2 | 7.2 ± 0.4 | 6.9 ± 0.3 | 7.3 ± 0.3 |
| | 2 | 7.5 ± 0.2 | 7.4 ± 0.2 | 7.3 ± 0.3 | 7.2 ± 0.3 | 6.9 ± 0.2 | 7.3 ± 0.2 |
| neem leaf powder | 1 | 7.4 ± 0.3 | 7.4 ± 0.3 | 7.4 ± 0.2 | 7.2 ± 0.2 | 6.8 ± 0.3 | 7.2 ± 0.3 |
| | 2 | 7.4 ± 0.2 | 7.4 ± 0.2 | 7.3 ± 0.3 | 7.0 ± 0.3 | 6.8 ± 0.2 | 7.2 ± 0.3 |
| neem kernel powder | 1 | 7.5 ± 0.4 | 7.3 ± 0.3 | 6.5 ± 0.2 | 7.1 ± 0.2 | 4.6 ± 0.3 | 6.6 ± 0.2 |
| | 2 | 7.4 ± 0.2 | 7.2 ± 0.2 | 6.0 ± 0.4 | 7.1 ± 0.2 | 3.9 ± 0.2 | 6.2 ± 0.2 |
| neem oil | 1 | 7.2 ± 0.3 | 7.1 ± 0.3 | 5.6 ± 0.3 | 6.9 ± 0.3 | 4.1 ± 0.3 | 6.2 ± 0.3 |
| | 2 | 7.0 ± 0.4 | 7.0 ± 0.3 | 4.9 ± 0.3 | 6.8 ± 0.2 | 3.0 ± 0.2 | 5.7 ± 0.3 |
| control (uninfested) | 0 | 7.5 ± 0.3 | 7.5 ± 0.2 | 7.4 ± 0.3 | 7.2 ± 0.2 | 7.0 ± 0.3 | 7.3 ± 0.3 |
| treatment | SE (*m*) | 0.69 | 0.52 | 0.51 | 0.50 | 0.56 | 0.40 |
| | CD ($P < 0.05$) | NS[a] | NS | 1.52 | NS | 1.68 | 1.20 |
| concn | SE (*m*) | 0.70 | 0.51 | 0.52 | 0.49 | 0.54 | 0.38 |
| | CD ($P < 0.05$) | NS | NS | NS | NS | NS | NS |
| treatment × concn | SE (*m*) | 1.21 | 1.10 | 1.12 | 1.00 | 1.13 | 0.69 |
| | CD ($P < 0.05$) | NS | NS | NS | NS | NS | NS |

[a] Not significant.

limits in terms of nutritional losses (Jood, 1990). Weight losses in kernels were proportional to the level of insect damage. Maximum loss (10.2%) was recorded in control, followed by garlic-treated kernels (5.2%). Neem kernel powder and neem oil treated kernels did not show any weight losses. Insecticidal properties of neem products against *T. granarium* and stored grain pests have been reported in several studies (Ketker, 1986; Singh and Kataria, 1986; Chellayan and Karnavar, 1990). Neem seed powder at the rates of 1, 2.5, and 5% (Singh and Srivastava, 1980) and 2% (Jotwani and Sircar, 1965) mixed with wheat grains provided protection against major pests for 3–10 months. Azadirachtin, a tetraterpenoid in neem seed, has the highest biological activity, antifeeding property, and developmental abnormalities against insect pests (Subrahmanyam, 1990). Chellayan and Karnavar (1990) observed that neem seed kernel extract inhibits normal pupal–adult development of *T. granarium*. Podina leaf powder was found to be effective against *Sitophilus oryzae* L. (Kashyap *et al.*, 1974), but in the present study it suppressed *T. granarium* population for only 4 months. Garlic powder was least effective, but in stored pulses it

**Table V. Effect of *T. granarium* Infestation on Organoleptic Characteristics of Maize Treated with Some Plant Protectants after 6 Months of Storage (Values Are ±SD of Mean Score of 10 Panelists)**

| treatment | concn, % | infestation level, % | color | appearance | aroma | texture | taste | overall acceptability score |
|---|---|---|---|---|---|---|---|---|
| citrus leaf powder | 1 | 43 | 7.2 ± 0.5 | 7.2 ± 0.3 | 7.0 ± 0.3 | 6.9 ± 0.6 | 5.3 ± 0.7 | 6.7 ± 0.3 |
| | 2 | 40 | 7.2 ± 0.3 | 7.2 ± 0.2 | 6.9 ± 0.3 | 6.9 ± 0.7 | 5.4 ± 0.6 | 6.7 ± 0.4 |
| garlic powder | 1 | 62 | 6.8 ± 0.9 | 6.8 ± 0.1 | 5.8 ± 0.4 | 6.1 ± 0.6 | 1.0 ± 0.8 | 5.3 ± 0.5 |
| | 2 | 55 | 6.8 ± 0.7 | 6.8 ± 0.4 | 6.0 ± 0.4 | 6.3 ± 0.7 | 1.2 ± 0.6 | 5.4 ± 0.2 |
| podina leaf powder | 1 | 40 | 7.0 ± 0.6 | 7.0 ± 0.3 | 6.9 ± 0.4 | 6.8 ± 0.5 | 4.9 ± 0.6 | 6.5 ± 0.3 |
| | 2 | 35 | 7.0 ± 0.5 | 7.0 ± 0.2 | 6.9 ± 0.4 | 6.8 ± 0.5 | 5.2 ± 0.5 | 6.6 ± 0.3 |
| neem leaf powder | 1 | 35 | 7.1 ± 0.5 | 7.0 ± 0.2 | 7.0 ± 0.4 | 6.9 ± 0.5 | 4.7 ± 0.5 | 6.5 ± 0.3 |
| | 2 | 30 | 7.0 ± 0.3 | 6.9 ± 0.5 | 6.9 ± 0.3 | 6.8 ± 0.5 | 5.0 ± 0.4 | 6.5 ± 0.1 |
| neem kernel powder | 1 | 0 | 6.9 ± 0.1 | 6.8 ± 0.6 | 6.9 ± 0.3 | 6.8 ± 0.6 | 4.5 ± 0.7 | 6.4 ± 0.2 |
| | 2 | 0 | 6.9 ± 0.5 | 6.8 ± 0.3 | 6.7 ± 0.2 | 6.6 ± 0.4 | 4.2 ± 0.6 | 6.2 ± 0.4 |
| neem oil | 1 | 0 | 6.9 ± 0.5 | 6.9 ± 0.6 | 6.9 ± 0.5 | 5.9 ± 0.3 | 3.9 ± 0.3 | 6.1 ± 0.5 |
| | 2 | 0 | 6.9 ± 0.3 | 6.7 ± 0.4 | 6.6 ± 0.5 | 5.8 ± 0.3 | 3.6 ± 0.5 | 5.9 ± 0.4 |
| control (uninfested) | 0 | 0 | 7.4 ± 0.5 | 7.4 ± 0.3 | 7.2 ± 0.2 | 7.2 ± 0.8 | 7.0 ± 0.6 | 7.2 ± 0.3 |
| treatment | SE (*m*) | | 0.30 | 0.25 | 0.40 | 0.24 | 0.51 | 0.35 |
| | CD ($P < 0.05$) | | 0.90 | 0.71 | 1.20 | 0.71 | 1.50 | 1.02 |
| concn | SE (*m*) | | 0.12 | 0.14 | 0.19 | 0.11 | 0.40 | 0.25 |
| | CD ($P < 0.05$) | | NS[a] | NS | NS | NS | NS | NS |
| treatment × concn | SE (*m*) | | 0.61 | 0.49 | 0.78 | 0.38 | 0.96 | 0.70 |
| | CD ($P < 0.05$) | | NS | NS | NS | NS | NS | NS |

[a] Not significant.

was very effective against *Callosobruchus maculatus* F. (Sowunmi and Akinnusi, 1983; Haque, 1987). These differences in efficacy may be due to insect species, the type of stored commodity, and the length of the storage period.

**Effect on Nutritional Composition.** Nutritional composition of plant product treated kernels (without insects) after 1 month remained unaffected (Table II). Variations in moisture (11.00–11.26%), ash (1.50–1.58%), crude fiber (2.20–2.22%), crude fat (3.29–3.60%), total protein (11.38–11.50%), and total carbohydrates (70.09–70.49%) contents of treated and untreated kernels were nonsignificant. This indicated that absorption/adsorption of plant products in kernels at an early stage of their treatment has no adverse effect on chemical composition. However, after 6 months of treatment in association with *T. granarium* feeding, there were significant changes in the level of nutritional compounds when compared between plant product treated and untreated (insect free) kernels. Changes were proportional to the degree of insect infestation. Neem kernel powder and neem oil offered complete protection to kernels for 6 months (Table III) without affecting nutritional composition. In other treatments, infestation ranged from 32.50 to 58.50%, resulting in a significant ($P < 0.05$) decrease in total carbohydrates and fat and an increase in moisture, fiber, and total protein. Such changes are associated with insect infestation in several stored grains (Swaminathan, 1977; Sharma *et al.*, 1979; Jood, 1990; Jood *et al.*, 1993).

**Effect on Organoleptic Characteristics.** Chapatis prepared from flour of plant product treated kernels after 1 month of storage were of normal color, appearance, and texture in all treatments (Table IV). However, taste and aroma of chapatis were unacceptable in garlic powder, neem kernel powder, and neem oil treatments. These characteristics also adversely affected the overall acceptability score. Plant products in association with *T. granarium* (Table V) after 6 months of storage did not cause significantly adverse effect on color and appearance of chapatis. Neem oil and neem kernel powder produced unacceptable taste. Moderate levels of insect infestation (30–43%) in neem, podina, and citrus leaf powder treated kernels also showed adverse effect on taste. Garlic-treated kernels were unacceptable in terms of aroma, texture, taste, and overall acceptability, as these were also heavily infested (55–62%) by insects. Smith *et al.* (1971) also observed distinct offensive taste and odor of breads prepared from wheat flour infested with stored grain pests.

It may be inferred from the present studies that neem products, viz. kernel powder and oil, proved to be very effective in preventing qualitative and quantitative losses in maize kernels by *T. granarium* for 6 months, but they produced adverse effect on the taste and overall acceptability of chapatis. Hence, it is not desirable to mix them in grains meant for human consumption.

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