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Processing of fruits and vegetables for its juicing: A Review

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ABSTRACT

Fruits and vegetable are important sources of vitamins, minerals, carbohydrates, phytochemicals and salts required for human nutrition in daily diet.Current food trend toward healthier diets makes fruit and vegetable juices consumption an important natural food alternative and improves the availability of its nutritive compounds.These commodities have higher edible index, which proves its importance for processing. By adopting some of the modern juice processing technologies after harvest, a significant portion at present that was getting spoilt can be salvaged. However, fruit and vegetable juices in its pure form have some typical colour, off-flavour and unpleasant taste due to their chemical compositions.Organoleptic quality of such fruit and vegetable blended juices could be increased by addition of spice extracts having anti-bacterial and anti-fungal properties. The presence of residual endogenous enzymes in fruit and vegetable which may cause quality changeshence required adequate thermal processing.Processing of juices by heat for a sufficient time is highly essential to kill micro-organisms which cause spoilage during storage period.Formulation and blending enables retaining more colour, consistency, fresh flavour and ascorbic acid content of juice products.The present review focuses on the various technical aspects of blanching of fruits and vegetables, formulations,blending, thermal processing and storage characteristicsfor the productionof blended juices, RTSbeverages and health drinks.

Key words : Juice, blanching, formulation, blending, thermal processing, storage

India is the second largest fruits and vegetables producing country in the world next only to China. Production of fruits is estimated about 88.97 million metric tons from an area of 7.21 million hectares at an average yield of 12.33 metric tons per hectare while vegetables is estimated about 162.89 million metric tons from an area of 9.39 million hectares at an average yield of 17.34 metric tons per hectare (National Horticulture Board, 2014). Vegetable and fruits are important sources of vitamins, minerals, carbohydrates, phytochemicals and salts required for human nutrition in daily diet and are available at a cheaper rate. Most fruit and vegetables are seasonal and supply is not uniform through the year. They are still underutilized in spite of being one of the cheapest source of nutrients and potential source of natural antioxidants and hence, steps should be taken to preserve it by extending the shelf -life in fresh form or in the processed form. As India is one of the major producers of these commodities and having higher edible index, which also proves its importance for processing (Sawate *et al.*, 2009). Production of juice is one way to make diversified process product from it to make best use of these commodities.

Current food trend toward healthier diets makes fruit and vegetablejuices consumption an important natural food alternative and improves the availability of its nutritive compounds. Traditionally, the Indian life style has a predilection for fresh fruits and vegetables or those processed at home. There is a sea change. People, are now increasingly going in for fresh fruit vending from kiosk fountains, which produce instant juices from fresh fruits and vegetables in the presence of the consumer. It could be due to the non-availability of hygienically produced and well-preserved products with the use of modern processing technology. The fluid expressed from excessively acid fruits is certainly juice, but the liquid is too sour to consume directly without dilution with sugar and water. The fruit drinks are mainly based on fruits andthey only differ in juice

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or pulp contents. The fruit drinks are mainly based on fruits and they only differ in juice or pulp contents. Many fruit juices are the obvious result of expressing the liquid from the whole or cut fruits. As per food safety and standards act; 2006, juice is the unfermented but fermentable product intended for direct consumption obtained from the edible part of one or more sound fruits or vegetables. It may be clear, turbid or pulpy, may have been concentrated and reconstituted with water suitable for the purpose of maintaining the essential composition and quality factors of the juice and processed by heat, in an appropriate manner, before or after being sealed in a container, so as to prevent spoilage (Nijhawan, 2012).

Fruit and vegetable juice consumption overall has increased in recent years probably due to public perception of juices as a healthy natural source of nutrients (USDA, 2012). Fruit and vegetable juices in the form of blended are also gaining popularity in the market as health drinks. Organoleptic quality of such fruit and vegetable blended juices could be increased by addition of spices extract of ginger, basil and mint, etc. Ginger juice has anti-bacterial and anti-fungal properties (Bhardwaj and Mukherjee, 2011). The ginger juice also acts as a good source of natural preservative (Kalpana *et al*, 2008). Ginger blended juice can improve the storability with minimal physicochemical changes and inhibits the microbial growth owing to its inherent antioxidant and antimicrobial properties (Ghosh *et al.*, 2011).This may be attributed to change in dietary habits, taste preferences, and the way of life of present-day consumers. By adopting some of the modern technologies for processing and preservation of it after harvest, a significant portion at present that was getting spoilt can be salvaged.

Processing

Fruit and vegetable juices have their best test, aroma and colour when they are freshly extracted or expressed. All subsequent efforts to process them adversely affect their quality to varying degrees, depending upon the method of production and preservation process employed. The most important problem therefore is to adopt only such methods as would help to retain their quality to the maximum extent possible.

Effect of blanching as pretreatment

Fruit and vegetable juices in general, in its pure form has some typical colour, off-flavour and unpleasant taste (Silva and Paul, 2004). The most probable enzymes responsible for this are peroxidase (POD) and poliphenoloxidase (PPO) (Calabrese *et al.*, 1999). Peroxidase (POD) is an enzyme conventionally used to monitor and evaluate the heat treatment extent, since it is one of the most heat stable enzymes(Silva and Paul, 2004). Peroxidase (POD) inactivation is usually used to indicate the adequacy of blanching treatments (Burnette, 1977). The presence of residual endogenous enzymes in juice may cause quality changes, such as texture changes and nutritional losses during storage.There is an empirical relationship between residual peroxidase activity and the development of off-flavors and off-odors in foods. Inadequate thermal processing may also result in regeneration of the enzyme.

Determining the quantitative peroxidase enzyme activities was carried in some vegetables and its resistance to heat by Muftugil, (1985) and concluded that the inactivation of peroxidase enzyme wasvery much depends on time and temperature of the blanching media and size of fruits and vegetables. Shivhare *et al.*, (2009) studied the optimization of blanching process for carrots. Investigations were carried out for evaluating the effect of selected blanching treatments on the quality of carrots over a temperature range of 80-100°C. They found that the most effective blanching treatment was 5 min in hot water at 95°C for 10 mm thick slices. At this time–temperature combination, POD and catalase were completely inactivated.To provide preliminary information on suitability of preparation for frozen and ready to use products,Calabrese *et al.*,(1999) studied bottle gourd (*L. siceraria*) fruit. For this 10 mm thick slices of fruits were blanched for 0-240 seconds in boiling water. After blanching, they were cooled in cold water for 5 minutes. POD and PPO activity were evaluated in relation to blanching period. The total enzymatic inactivation of blanched samples (residual peroxidase activity < 1 %) was obtained when blanched for 180 sec. James and Shen (2011) also described the most of the vegetables need to be blanched at a temperature high enough to inactivate the enzyme during the early stage of processing. Gajera *et al.*,(2014) carried out blanching process for the inactivation of the POD enzymein bottle gourd fruits prior to juicing and the best water blanching treatment was found at 100°C for 3.67 min in 5 mm bottle gourd slices based on selected process parameters.In addition to inactivation of enzymes, blanching of the aonla fruits prior to juice extraction significantly improved the juice recovery(Jain and Khurdiya, 2002).Preparing and evaluating bottle gourd fruit RTS beverage by Sawate *et al.*, (2008) concluded that blanching is effective for the extraction of juice.

Minimal blanching for not more than 5 min at 98 °C was also recommended by Amin and Lee, (2005) to prevent the major loss of antioxidant activity of vegetable components.Theabove results were very much similar to result reported by Liao *et al.*, (2007) studding the effect of enzymatic mash treatment of carrot juice concluding an increase of juice yield, TSS and carotenoid in carrot juice (20%, 1% and 26 mg/ kg, respectively).

Effect of formulations

Formulation is an important process enables retaining more color, consistency, fresh flavor, and ascorbic acid content of juice products. Microorganisms, including yeasts, molds and bacteria are sensitive at very low or high values of pH, yeasts and molds can tolerate lower pH conditions than most bacteria (William, 2011).The change in acidity may result in the protonation or de-protonation in juice, which leads to change the structure and functions (Beattie and Pedeeson, 2006; Derossi *et al.*, 2011). This is the mechanisms by which pH reduction allows to prevent the growth of spores, to reduce the heat resistance of microorganisms, and to decrease their growth rate.

Bawa and Bains (1977) developed watermelons juice extracted mechanically from cut fruit had an insipid taste. The possibility of improving taste of juice was studied by increasing the sugar content to about 3% and the acidity factor by 0.2% as citric acid. Similar studies were carried out by Gowda and Jalani, (1995) for juice making from watermelon by addition of salt (1%); sugar (2%), citric acid (0.3%) and ginger extract (0.3%) or spice extracts of cardamom, cinnamon and pepper @ 0.25% each and concluded that the adjustment of TSS and acidity along with ginger extract improved overall acceptability significantly but addition of salt and spices did not improve the overall acceptability of the juice. Grewal and Jain (1982) studied the physicochemical characteristics formulating carrot juice beverages. Fresh carrot juice was standardized as preserved carrot juice and milk based carrot juice beverage. The bitterness of carrot juice could easily be overcome by a common blend of 0.6% salt and 8.0% cane sugar. The preserved carrot juice beverage was quite acceptable at 3.6 pH adjusted by citric acid. A 20% mix of carrot juice with skim milk was easily sterilized at 116°C/30 minutes to yield acceptable quality. Jain and Khurdiya (2004) studied vitamin C enrichment of fruit juice based ready-to-serve beverages through blending with Indian gooseberry (*Emblica officinalis* gaertn.) juice. On the basis of overall sensory quality and vitamin C content, RTS beverage prepared by blending gooseberry juice in 20:80 ratios was found to be the best.Polyphenolrich beverages were prepared using lemon and pomegranate juices in different proportions (at 25%, 50% and 75% for both juices) by Molina *et al.*, (2009) and result suggested that the new drink made of 75% of pomegranate juice and 25% of lemon juice (v:v) has potential for development of new healthy beverages food products, emphasized by its high antioxidant capacity determined by its phenolic composition, anthocyanin and vitamin C and improved colour properties. Molina *et al.*, (2009) studied formulation of a new drink rich in healthy bioactive combining lemon and pomegranate juices. For this, polyphenol-rich beverages were prepared using lemon and pomegranate juices in different proportions (at 25%, 50% and 75% for both juices). The bioactive composition (flavonoids and vitamin C) of the mixtures as well as its stability, antioxidant capacity and changes in colour over a 70 days storage period were studied. The result suggested that the new drink made of 75% of pomegranate juice and 25% of lemon juice (v:v), has potential for development of new healthy beverages or food products, emphasized by its high antioxidant capacity (determined by its phenolic composition, anthocyanins and vitamin C) and improved colour properties.

Effect of blending

Blending of juice is a promising way of utilizing under-utilized vegetables, fruits and spices (Bhardwaj and Pandey, 2011). This may be attributed to change in dietary habits, taste preferences, and the way of life of present-day consumers. During the last few years the demand for fruit and vegetable blended juice has been increasing. Contrary to this, the fruit and vegetable blended juice industry in India is still not in sound footing. Therefore, to improve upon the taste, aroma, palatability, storability and nutritive value of juices, it is convenient to blend it with each otherto prepare natural health drink having adequate shelf-life.

Processing and storage stability of blended ash gourd (*Benincasa hispida*) and mint leaves (*Mentha spicata*) juice was studied by Majumdar *et al.*, (2009). The juice was blended in 75: 25 (ash gourd juice: mint leaves juice). Food grade sugar and lemon juice were added and final pH was adjusted to 4.0 using lemon juice itself. Naik *et al.*, (2009) studied the whey based watermelon beverage prepared by blending watermelon juice (15%), sugar (7%) and different concentrations of betel leaves distillate (0, 1, 2, and 3%) into chhanna

whey (78-75%). The sensory quality of fresh and stored (30 days) beverage containing 2% betel leaves distillate was highly acceptable. Addition of 3% betel leaves extended the storage life of the product.Evaluating the effects of fruit juice blending on kinnow juice preservation at ambient storage condition for improving flavour, nutritive and medicinal value by Bhardwaj and Mukherjee, (2011). For this different fruit juice blends were prepared as (Kinnow juice: Aonla juice: Ginger juice in 100: 0: 0, 95: 5: 0, 92: 5: 3 ratio and Kinnow juice: Pomegranate juice: Ginger juice in 90: 10: 0, 87: 10: 3 ratio) for improving flavour, nutritive and medicinal value. It was observed that the kinnow juice blend with pomegranate and ginger juice in the ratio of 87:10:3 was the most effective and the addition of ginger juice in blends improved the quality and reduced the microbial growth. Juice blends as a way of utilization of under-utilized fruits, vegetables, and spices was reviewed by Bhardwaj and Pandey (2011). Authors concluded that the utilization of highly nutritive fruits and vegetables is limited due to their high acidity, astringency, bitterness, and some other factors. For improving quality of various fruit juices such as aonla, mango, papaya, pineapple, citrus, ber, pear, apple, watermelon, and vegetables including bottle gourd, carrot, beet root, bitter gourd, medicinal plants like aloevera, blending can be effective and useful.

The effect of storage on physicochemical, microbiological and sensory quality of bottle gourd (*L.siceraria*)- basil leaves (*Ocimum sanctum*) juice blend was studied by Majumdar *et al.*, (2011). For this, individual blanching was carried out in boiling water for 2 min and juice was extracted by mechanical juice extractor. Bottle gourd juice, basil leaves juice and lemon juice were selected as independent variables having actual levels ranged from 50 to 75, 25 to 50 and 5 to 10 ml, respectively, while the overall sensory scores and acidity of the product were the responses. Food grade sugar and salt were added to the juice to improve the taste and flavour. The effects of independent variables revealed that bottle gourd and basil leaves juice showed the lowering in acidity of juice blend while lemon juice levels proportionately elevated acidity of the juice blend. The increase in the level of basil leaves had a reduced sensory response. A refreshing beverage from mature coconut water blended with lemon juice was studied by Chauhan *et al.*, (2012). Coconut water obtained from the mature coconuts and blended with lemon juice to develop a refreshing beverage. An optimum condition for the coconut water beverage was obtained at 13.5 °Brix blended with 2 % lemon juice. The mature coconut water beverage blended with lemon juice showed a shelf-life of 6 months in packed conditions at low (5 °C), ambient (25 ± 2 °C) and high (37 °C) temperatures on the basis of physicochemical, microbiological and sensory attributes. Jan *et al.*, (2012) evaluated quality of pineapple juice blend with carrot and orange juice in different ratios. The juices of carrot, pineapple and orange were blended in different ratios of 100:0:0, 80:10:10, 60:10:30, 50:20:30 respectively and sugar and citric acid were added. It was concluded that the pineapple juice: carrot juice: orange juice (60:10:30) was the most effective juice blend for minimum change in TSS (10 to 12 °Brix), acidity (0.97-1.83%), vitamin C (19.50) and beta carotene (1583µg). Sensory evaluation was also higher and better consistency score up to the end of storage. The product was microbiologically safe during 21 days of storage with good acceptability. Results revealed that the formulation of mixed blend juice beverage is possible to satisfy consumer taste and preferences. Kausar *et al.*, (2012) studied the development and storage stability of cucumber (*Cucumis sativus*) - melon(*Cucumis melo*) functional blend drink. These ready-to-use functional drinks were prepared by blending different ratios of cucumber and muskmelon (100:0, 90:10, 80:20, 70:30, and 60:40).The physicochemical parameters and sensory characteristics of blended drinks were evaluated for 4 months at 15 days of storage interval. It was observed that mean values of TSS (15.49-16.09%), acidity (0.41-0.51%) and reducing sugars (1.9-2.48 %) was increased while pH (4.89-4.82) and non-reducing sugars (9.36-8.70 %) was decrease during storage. Regarding sensory attributes, maximum scores (7.51) for overall acceptability was observed in cucumber and muskmelon ratio of 90:10. The study concluded that cucumber-melon pulp functional drink prepared at 90:10 was the most acceptable for minimum changes in TSS, acidity, pH, reducing and non-reducing sugar. Combinatory effect of thermal treatment and blending on the quality of pomegranate juices was studied by Mena *et al.*, (2012). A pure mono varietal juice, a combination of two widely distinct varietal juices (75 % Mollar de Elche + 25 % Wonderful) and a blend of pomegranate juice plus lemon (75 % + 25 %, respectively) were compared. Results displayed how blending can protect the desirable properties of pomegranate juices better than pure mono varietal juices.

Effect of thermal processing

Thermal processing of fruit juice by heat is the most popular method. The method consists essentially in heating the juice to 100 °c or slightly below for a sufficient time to kill micro-organisms, which cause spoilage. Usually, the juices are thermally processed at about 75-100 °c / 05-30 min according to the nature of the juice and the size of container (Bawa and Bains, 1977; GirdhariLal *et al.*, 1986; Gowda and Jalani, 1995; Jainand Khurdiya, 2004; Demir *et al.*, 2007; Li *et al.*, 2009; Jan and Masih, 2012).

Watermelon juice was processed by Bawa and Bains, (1977) heating it in a steam jacketed kettle at 75-80°C for about 5 minutes and hot filled to 650 ml glass bottles for further processing by immersion in boiling water for 50 min had higher shelf-life at room temperature.GirdhariLal *et al.*, (1986) described the most popular preservation method of fruit juices by application of thermal treatment up to 100°C or slightly below for a sufficient time.Further they described that the yeast and acid-tolerant bacteria are readily killed if the juice is heated at about 66°C for a few minutes andmould spores are destroyed at 79°C for 5 -10 min. Therefore, usually the juices are processed at about 85°C for 25-30 min according to the nature of the juices and size of the containers. Beattie and Pedeeson (2006) has also studied celery juice acidified to 0.3% acid and concluded that juice could be processed safely at 100°C, without coagulating and having more pleasing flavor than the non acidified juice. Demir *et al.*, (2007)studied the effect of processing method of carrot juicefilled in bottles and processed at 85°C for 15 minshowed that increasing the acidity of mash with citric acid addition increased the juice yield.

Effect of thermal processing at 91°C for 20 min on quality related attributes of longan juice was studied by Li *et al.*, (2009) concluded that the heat-treated juice had a higher translucency and lower concentrations of pectin, phenolic compounds and proteins, compared with the non heat-treated juice. Result suggests that the thermal processing exhibits a potential for quality maintenance of juice. Similarly, Majumdar *et al.*, (2009) and Majumdar *et al.*, (2011) studied processing of ash gourd (*Benincasa hispida*)-mint leaves (*Mentha spicata*) and bottle gourd- basil leaves juices, respectively pasteurizing in hot water at 95°C for 15 min concluding that there were slight changes of quality with no significance difference at 95% confidence level. Evaluating quality of pineapple juice blended with carrot and orange juice, Jan and Masih, (2012) carried out an experiment by fillingjuice in 400 ml PET bottles and sterilized at 110°C for 10 min followed by pasteurized at 90°C for 25 sconcluded that the product was microbiologically safe up to3 weeks with good acceptability. Mena *et al.*,(2012) studied effect of thermal treatment on the quality of blend pomegranate juices comparing after pasteurization at two different heat treatments concluded the HTST exhibited a higher protective role than LTLT. Gajera and Joshi (2014) carried out thermal processing of blend juice at various time and temperatures along with its pH stability test to optimize the process as per food safety andstandards rules and regulationsand,the best thermal process was found at 85°C hot filled, and processed at 85°C for 5 minin the glass bottles.

Effect of storage on quality

Storage studies are extremely important to check the quality and shelf- life of thermally processed juice or its products. Physicochemical and microbiological quality of such products should be stable as possible as during designated storage conditions.

Bawa and Bains (1977) processed water melon juice and stored at room temperature (35-38°C) found that the untreated juice bottles exhibited microbial fermentation within a week while, heat processed bottles had higher shelf-life. Studied an effect of storage on quality of stone apple ready-to-serve beverage by Kalpana *et al.*, (2008) found all the biochemical qualities changed with storage period irrespective of the treatments. Li *et al.*, (2009) studied changes in quality attributes of longan juice during storage concluded that the thermal processing maintained higher concentrations of total soluble solids and total acidity but a lower ascorbic acid concentration. Majumdar *et al.*, (2009) studied storage stability of blended ash gourd juicefound slight changes of pH, TSS and total acidity (as citric acid) of the juice during storage up to 6 months. Bhardwaj and Mukherjee (2011) evaluated kinnow based blended juice preservation at ambient storage conditionfor 6 months observed that the addition of ginger juice in blends improved the quality and reduced the microbiological growth. Jan and Masih (2012) stored pineapple juice blend with carrot and orange juicefor 21 days concluded that the pineapple juice: carrot juice: orange juice (60:10:30) was most effective juice blend for minimum change in TSS (10 to 12°Brix), acidity (0.97-1.83%), vitamin C (19.50) and beta carotene (1583µg). Studied the development and storage stability for 4 months of cucumber (*Cucumis sativus*)-melon(*Cucumis melo*) functional drink by Kausar

et al., (2012) observed that the mean values of TSS (15.49-16.09%), acidity (0.41-0.51%) and reducing sugars (1.9-2.48%) was increased while pH (4.89-4.82) and non-reducing sugars (9.36-8.70%) was decreased during storage. Similarly, Gajera and Joshi, (2015) studied the quality evaluation of bottle gourd (*L.Siceraria*) based blend juice during ambient storage conditionfound that the no significant difference (P>0.05) was inpH, total soluble solids, total acidityand most sensory attributes of the product during initial 30 days of storage. However, significant difference (P<0.05) was observed in ascorbic acid content, sugars and microbiological counts during further storage and theproductwas microbiologically safe up to 180 days storage.

CONCLUSION

Fruits and vegetables are available at relatively cheaper rate during glut season. Considerable portions of the produce are lost due to lack of processing at this time. To utilize the surplus production and avoid post-harvest losses, fruits and vegetables may be suitably processed into processed productslike juices, RTS beverages and health drinks which will containsfairamount of vitamin C (ascorbic acid), carbohydrate and minerals. Juice in its pure form has browning colour, off-flavour and unpleasant taste.To overcome this problem, blanching is an important unit operation and is necessary for inhibition of enzymes action prior to processing of fruits and vegetables.The proper formulation and blending ofthe juice productsare highly required for the market acceptance in terms of sensory attributes and the physicochemical parameters to meet the criteria of food safety and standard regulations, 2006. To preserve the quality and shelf- life of juice products along with maximizethe retention of ascorbic acid and to minimize the microbiological counts,thermal processing at various time and temperatures areutmost important.To check stability of the thermally processed juice products,storage study at different conditions exhibit an important role tohave an adequate self-life and good acceptability as it satisfies the sensory, physicochemical and required microbiological criteria.

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Heterosis for grain yield components in Pearl millet [*Pennisetum glaucum* (L) R.Br.]

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ABSTRACT

An experiment comprised of 70 genotypes consisting of 54 hybrids resulting from Line x Tester mating design involving 15 parental line and standard check (GHB-558) was conducted at Center for Crop Improvement, S.D.Agricultural University, Saradarkhushinagar (Gujarat) during *kharif*-2014 for studying the extent of hybrid vigour in F_1 for grain yield and its components. The hybrid ICMA-96333 X J-2454 show significant positive relative heterosis, heterobeltiosis and standard heterosis for harvest index and protein content and also showed significant positive standard heterosis for Zn content and hybrid JMSA-20072 x J-2512 showed significant positive standard heterosis for Fe content. The significant economic heterosis in desirable direction was observed in most of the high heterotic hybrid of a grain yield per plant number of effective tillers per plant and Zn content which indicating that the maximum contribution of this character towards yield heterosis.

Key words : Heterosis, heterobeltosis, standard heterosis, pearl millet

Pearl millet [*Pennisetum glaucum* (L) R.Br.] is a stable diet for the vast majority of poor farmers and also form an important fodder crop for livestock population in arid and semi-arid region of India. Heterosis breeding has been recognized as the most suitable breeding methodology for augmenting yield in pearlmillet. Selection of suitable parents and assessment of degree of heterosis in the resulting crosses forms an important step. In relation to the yield,quality traits have also important role for increasing value addition because pearl millet grain is richer source of starch (56.05-73.37) (Choudhary, 2005), fat (1.5-9.9%), protein (6.40-24.25%), iron (30.1–75.7 mg/kg) and zinc (24.5– 64.8 mg/kg) (Velu,2011) phosphorous (185.0-363.0 mg/100g) and total carotenoids (84-445 mg/100g) (Sharma, 2005). An extensive survey of pearl millet literature showed 40% average better parent heterosis for grain yield. Previous studies showed that, high amount of heterosis for grain yield and harvest index, high magnitude of heterosis for grain yield and standard heterosis for grain yield, effective tillers per plant, ear head leangth, ear head girth, test weight. Heterosis breeding was ideal for increasing yield in pearl millet. Therefore the present investigation was conducted to study the extent of hybrid vigour in F_1 for grain yield and its components.

MATERIALS AND METHODS

In present study fifty-four crosses were made during summer 2014 using the 6 male sterile line and 9 tester. The parents were obtained from Main Bajara Reserch Station, Junagadh Agricultural University, Jamnagar. Thus, present investigation carried out using 54 hybrids and 15 parents along with standard check GHB-558 formed with Rendomized Block Design (Kempthorne,1957) with three replication at Center for Crop Improvement, S.D. Agricultural University, Saradarkhushinagar (Gujarat) during *kharif*-2014. Each hybrid and parents represented two rows having 4 m length spaced at 45 cm between row and 15 cm apart from plant to plant within row. Uniformed and recommended cultural practices were followed to raise agronomically good managed crop. The observations were recorded on five randomly selected competitive plant from each replication for 12 traits, *viz.*, Days to

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flowering, Days to maturity, Plant height (cm), Effective tillers per plant, Ear head length(cm), Ear head girth(mm), Test weight(g), Grain yield per plant(g), Harvest index (%), Protein content(%), Fe content(mg/kg), and Zn content(mg/kg). The expression of heterosis 54 hybrids involving 6 lines and 9 testers was measured in term of relative heterosis in relation to mid parent, heterobeltiosis in relation to better parent and standad heterosis in comparison with GHB-558, the hybrid as the standard.

RESULTS AND DISCUSSION

The analysis of variance for yield and its components traits in RBD revealed that the parents and their hybrids involved in the present study differed significantly for all the characters. Mean values of grain yield and yield component characters of parents (line and tester) and their hybrid is presented in Table 1. The ranged of mid parent heterosis, heterobeltiosis and standard heterosis as well as, number of hybrids showed significant heterosis in desirable direction in present in Table 2.

The extent of heterosis for days to flowering had range varied from -16.45 to 95.21 percent when all the three types were considered. The highest significant negative relative heterosis and heterobeltiosis was observed in cross JMSA-20072 X J-2512, Similar results were reported by Kushwah and Singh (1992), Kulkarni *et al.* (1993), Karale *et al.* (1997), Katti *et al.* (1997) and Yadav (2006). For days to maturity 16, 25, and 1 hybrids showing relative heterosis, heterobeltiosis, and standard heterosis respectively. The hybrid ICMA-842 X J-2496 showed highest significant relative heterosis, heterobeltiosis as well as standard heterosis for earliness over standard check GHB 558. Similar results were reported by Kushwah and Singh (1992) and Manga and Dubey (2004).

The extent of heterosis for plant height had range varied from -21.51 to 87.06 percent when all three types were considered. With respect to dwarfness the hybrid JMSA-9904 X J-2454, ICMA-96333 X J-2538 AND JMSA-9904 X J-2454 showed highest relative heterosis, heterobeltiosis and standard heterosis, respectively. These findings were in agreement with the reports of Kushwah and Singh (1992), Chavan and Nerkar (1994), Yadav (1999), Sheoran *et al.* (2000) and Yadav *et al.* (2006).

Number of effective tillers per plant is an important component of grain yield, for effective tiller per plant range of heterosis varied from -60.71 to 100.00 percent when all the three types were considered. For number of effective tillers per plant 22, 15, and 39 hybrids showing relative heterosis, heterobeltiosis, and standard heterosis respectively. Hybrid ICMA-96333 X J-2479, JMSA-20072 X J-2496 and JMSA-20042 X J-2510 showed relative heterosis, heterobeltiosis and standard heterosis, respectively, Similar results in all the three type of heterosis were also reported by Kushwah and Singh (1992), Patil *et al.* (1994), Balakrishnan and Das (1996), Karale *et al.* (1997), Manga and Dubey (2004) and Arulselvi *et al.* (2006).

For ear head length out of the 54 crosses, 44 crosses recorded significant positive relative heterosis in desirable direction, and the croas ICMA-08111 X J-2454 showed highest relative heterosis, 28 crosses manifested significant positive heterobeltiosis and the hybrid ICMA-08111 X J-2454 showed highest heterobeltiosis, 14 hybrids showed standard heterosis in positive direction and the cross JMSA-20042 X J-2510 showed desirable standard heterosis Same observation recorded for all three type of heterosis by Kushwah and Singh (1992), Kulkarni *et al.* (1993), Balakrishna and Das (1996), Karale *et al.* (1997), Katti *et al.* (1997), Ramamoorthi and Govindarasu (2000) and Manga and Dubey (2004). For ear head girth, out of 54 hybrids, 35 hybrids depicted significant positive heterosis over mid parent and 22 hybrids showed significant positive heterosis in desirable direction over better parent. The cross JMSA-20042 X J-2454 showed highest significant positive relative heterosis and heterobeltiosis, Azhaguvel *et al.* (1998) Sheoran *et al.* (2000) also supported these results., where as none of the hybrid showed positive economic heterosis, similar results were also reported by Kushwah and Singh (1992), Kulkarni *et al.* (1993), Patil *et al.* (1994), Balakrishna and Das (1996), Karale *et al.* (1997) and Katti *et al.* (1997).

The trait, test weight showed a range of -32.71 to 26.17 with 28 crossed exceeded the value of standard check (GHB-558). The cross JMSA-20042 X J-2507 registered highest relative heterosis, heterobeltiosis and standard heterosis. These findings were in agreement with the reports of Kushwah and Singh (1992), Kulkarni *et al.* (1993), Patil *et al.* (1994), Karale *et al.* (1997), Manga and Dubey (2004) and Arulselvi *et al.* (2006).

For grain yield per plant, the mid parent heterosis ranged from -32.88 to 105.75 percent, heterobeltiosis

Table 1 Mean value of grain yield and its component characters of pearl millet.

Charecters	Mean value			
	Line	Tester	Hybrids	C.D.%
Days to flowering	48.83	47.89	48.20	4.93
Days to maturity	78.60	77.53	77.60	4.67
Plant height (cm)	114.28	131.56	91.44	25.75
No. of effective tiller/ plant	2.05	1.88	2.00	0.40
Ear head length (cm)	18.53	19.29	20.85	2.32
Ear head girth (mm)	21.4	21.86	23.63	2.44
Test weight (g)	9.82	9.23	10.45	1.00
Grain yield/plant (g)	22.22	19.91	25.59	3.08
Harvest index (%)	29.47	27.08	31.09	3.02
Protein content (%)	8.92	8.04	8.87	0.74
Fe content (mg/kg)	70.17	32.07	50.11	2.35
Zn content (mg/kg)	41.73	11.90	21.32	1.64

ranged from -43.23 to 101.39 whereas, economic heterosis varied from -62.50 to 14.77 percent with 4 crosses yielded more than the standard check GHB-558. Out of 54 crosses, 39, 34 and 4 hybrids registered high significant positive heterosis over MP, BP and SC respectively for grain yield per plant. The crosses JMSA-20072 X J-2512, JMSA-20072 X J-2510 and JMSA-20072 X J-2479 showed high significant positive relative heterosis as well as heterobeltiosis. The highest standard heterosis for grain yield per plant recorded by the JMSA-20072 X J-2512 (14.77%), followed by ICMA-96333 X J-2454 (6.82%) and JMSA-20072 X J-2510 (5.97%) over the check GHB-558. Similar type of results for all heterosis also finding by Kushwah and Singh (1992), Penthani and Dave (1992), Kulkarni *et al.* (1993), Nijhawan and Yadav (1993), Izge *et al.* (2007) and Vaghasiya *et al.* (2009).

Harvest index is also important component for grain yield, for harvest index 38, 19 and 6 hybrid showed relative heterosis, heterobeltiosis, and standard heterosis respectively. The hybrid ICMA-9633 X J-2496 showed highest relative heterosis and heterobeltiosis, the results were supported by Deore *et al.* (1997) and JMSA-20072 X J-2454 hybrid showed highest significant positive standard heterosis, Nijhawan and Yadav (1993), Deore *et al.* (1997) and Manga and Dubey (2004) were supported this results.

For protein content, the perusal of estimate of relative heterosis indicated the 29 hybrids showed significant positive heterosis, 17 crosses showed significant positive heterobeltiosis and 9 crosses showed significant positive standard heterosis, where hybrid JMSA-20042 X J-2479 showed highest relative heterosis as well as heterobeltiosis and ICMA-96333 X J-2454 showed standard heterosis. The results were supported by Sukhchin and Phul (1990). In case of Fe content, hybrid ICMA-842 X J-2556 showed highest relative heterosis, heterobeltiosis and standard heterosis. For Zn content, 18, 8 and 52 hybrids showed relative heterosis, heterobeltiosis, and standard heterosis respectively, whereas hybrid ICMA-842 X J-2556 showed highest relative heterosis as well as heterobeltiosis and ICMA-08111 X J-2556 hybrid showed standard heterosis.

The general expectation of the pearl millet farmer is mainly focused on level of superiority of newly released hybrids than the local standard hybrids, which is grown widely. So there is a compulsion need for the breeder to evaluate the newly developed hybrids with such standard hybrids for yield or any other desirable characters. With this point of views the hybrids generated in the present investigation were evaluated and selected on their standard heterosis values. The hybrid *viz.*,JMSA-20072 X J-2512, ICMA-96333 X

Table 2 Range of heterosis, number of crosses showing desirable heterotic performance and best heterotic combination for yield and its components in Pearl millet

Character	Range of heterosis			No. of significant hybrids on the basis of			Best heterotic combination over					
							MP		BP		SC	
	MP	BP	SC	MP	BP	SC	Cross	Value	Cross	Value	Cross	Value
Days to flowering	-13.90 to 13.93	-16.45 to 13.98	-0.73 to 95.21	21	26	0	JMSA-20072× J-2512	-13.90	JMSA-20072× J-2512	-16.45	JMSA-20042× J-2496	-0.73
							JMSA-20042× J-2496	-13.68	JMSA-20042× J-2496	-16.33	-	-
							JMSA-20072× J-2496	-12.41	JMSA-20042× J-2507	-14.29	-	-
Days to maturity	-15.14 to 6.16	-16.03 to 4.60	-7.53 to 13.94	16	25	1	ICMA-842× J-2496	-15.14	ICMA-842× J-2496	-16.03	ICMA-842× J-2496	-7.53
							ICMA-08111× J-2496	-8.86	ICMA-08111× J-2496	-8.86	-	-
							JMSA-9904× J-2372	-4.44	JMSA-9904× J-2372	-5.44	-	-
Plant height	-11.80 to 47.06	-21.51 to 44.23	-21.09 to 87.06	5	16	20	JMSA-9904× J-2454	-11.80	ICMA-96333× J-2538	-21.51	JMSA-9904× J-2454	-21.09
							ICMA-96333× J-2538	-11.26	ICMA-842× J-2538	-16.93	JMSA-20042× J-2496	-17.29
							JMSA-9904× J-2496	-8.31	JMSA-20042× J-2538	-14.14	JMSA-9904× J-2496	-14.85
No. of effective tillers/plant	-48.84 to 71.43	-60.71 to 100.00	-38.89 to 78.95	22	15	39	JMSA-9904× J-2479	71.43	JMSA-20072× J-2496	100.00	JMSA-20042× J-2510	78.95
							JMSA-9904× J-2372	56.25	JMSA-9904× J-2507	66.67	JMSA-9904× J-2479	44.44
							ICMA-08111× J-2454	52.94	ICMA-96333× J-2479	60.00	ICMA-842× J-2454	38.89
Ear head length	-13.08 to 50.15	-22.32 to 44.09	-19.91 to 88.68	44	28	14	ICMA-08111× J-2454	50.15	ICMA-08111× J-2454	44.09	JMSA-20042× J-2510	88.68
							JMSA-9904× J-2507	45.64	JMSA-9904× J-2512	41.03	JMSA-20072× J-2538	27.60
							JMSA-9904× J-2512	44.26	JMSA-9904× J-2507	39.66	JMSA-9904× J-2507	16.74
Ear head girth	-18.72 to 53.81	-18.74 to 51.30	-30.82 to -4.11	35	22	0	JMSA-20042× J-2454	53.81	JMSA-20042× J-2454	51.30	-	-
							JMSA-20042× J-2496	53.78	JMSA-20042× J-2496	49.82	-	-
							JMSA-20042× J-2507	51.43	JMSA-20042× J-2507	45.64	-	-
Test weight	-28.95 to 46.93	-34.18 to 43.26	-32.71 to 26.17	47	41	28	JMSA-20042× J-2507	46.93	JMSA-20042× J-2507	43.26	JMSA-20042× J-2507	26.17
							JMSA-20042× J-2454	38.20	JMSA-20042× J-2538	33.21	ICMA-08111× J2556	17.76
							JMSA-20042× J-2538	34.69	JMSA-20042× J-2454	26.90	ICMA-08111× J-2507	16.82
Grain yield/ plant	-32.88 to 105.75	-43.23 to 101.39	-62.50 to 14.77	39	34	4	JMSA-20072× J-2512	105.75	JMSA-20072× J-2512	101.39	JMSA-20072× J-2512	14.77
							JMSA-20072× J-2510	102.17	JMSA-20072× J-2510	94.11	ICMA-96333× J-2510	6.82
							JMSA-20072× J-2479	86.91	JMSA-20072× J-2479	81.56	JMSA-20072× J-2510	5.97
Harvest index	-37.71 to 136.81	-40.81 to 69.39	-41.49 to 37.37	38	19	6	ICMA-96333× J-2496	136.81	ICMA-96333× J-2496	69.36	JMSA-20072× J-2454	37.37
							ICMA-96333× J-2512	111.18	ICMA-96333× J-2512	42.29	JMSA-20042× J-2454	10.57
							ICMA-96333× J-2372	73.78	ICMA-08111× J-2507	32.19	ICMA-96333× J-2512	8.76
Protein content	-26.34 to 44.44	-30.11 to 32.33	-29.47 to 17.89	29	17	9	JMSA-20042× J-2479	44.44	JMSA-20042× J-2479	32.23	ICMA-96333× J-2454	17.89
							ICMA-96333× J-2454	36.91	JMSA-20042× J-2454	27.90	JMSA-9904× J-2512	12.63
							JMSA-20042× J-2454	29.58	ICMA-96333× J-2454	24.13	JMSA-20072× J-2454	11.58
Fe content	-72.26 to 348.8	-83.85 to 242.73	-69.00 to 105.06	23	11	9	ICMA-842× J2556	348.80	ICMA-842× J2556	242.73	ICMA-842× J2556	105.06
							ICMA-842× J-2510	186.43	ICMA-842× J-2510	159.09	ICMA-842× J-2512	67.54
							JMSA-9904× J-2510	138.54	JMSA-9904× J-2510	122.33	ICMA-842× J-2510	54.97
Zn content	-84.37 to 484.81	-90.45 to 425.00	-25.37 to 1049.25	18	8	52	ICMA-842× J-2556	484.81	ICMA-842× J-2556	425.00	ICMA-08111× J2556	1049.25
							ICMA-842× J-2454	212.33	ICMA-842× J-2454	159.09	ICMA-08111× J-2479	541.79
							JMSA-9904× J-2496	124.44	JMSA-9904× J-2538	69.35	ICMA-842× J-2454	467.16

J-2454, JMSA-20072 X J-2510 and JMSA-20042 X J-2556 showed high per se performance with high significant relative heterosis, heterobeltiosis and standard heterosis for grain yield per plant respectively. The hybrid ICMA-96333x J-2454 show significant relative heterosis, heterobeltiosis and economic heterosis for harvest index and protein content and also showed significant positive standard heterosis for Zn content and hybrid JMSA-20072 x J-2512 showed significant positive standard heterosis for Fe content. The significant economic heterosis in desirable direction was observed in most of the high heterotic hybrid of a grain yield per plant, number of effective tillers per plant and Zn content which indicating that the maximum contribution of this character towards yield heterosis.

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Genetic parameters and character associations for yield and yield contributing traits in dual sorghum (*Sorghum bicolor* L. Moench)

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ABSTRACT

Thirty two advanced dual sorghum genotypes were evaluated at Sorghum Research Station, S. D. Agricultural Univeristy, Deesa during *Kharif* 2015 to study the genetic variability and genetic association for grain yield, fodder yield and their component characters. Both genotypic and phenotypic variances were highly significant in all the traits with little higher phenotypic variations as usual. Similarly, the low differences between the phenotypic and genotypic coefficients of variations indicated low environmental influences on the expression of these characters. High heritability coupled with high genetic advance in % of mean was obtained with panicle length, leaf length, leaf width, plant height, grain yield and fodder yield. Genotypic correlation coefficients were higher than the corresponding phenotypic correlation coefficients in most of the traits. Plant height, number of leaves/plant, leaf length, leaf width and days to maturity were the most important characters which possessed positive association with fodder yield. While panicle length was positively and significantly associated with grain yield. Path coefficient analysis revealed that among the different yield contributing characters fodder yield, panicle length and leaf length influenced grain yield directly while leaf width, number of leaves/plant, plant height, days to maturity and grain yield influenced fodder yield directly. The direct effects of these characters on grain yield and fodder yield were positive and considerably high. Thus the plant selection based on these traits will be most effective in the development of dual sorghum varieties.

Key words : Genetic variability, GCV, PCV, character associations, path analysis, genetic advance

Sorghum (*Sorghum bicolor* (L.). Moench) is the fifth most important food crop in world after wheat, rice, maize, and barley and fourth most important in the India after wheat, rice and maize. India contributes about 16% of the world's sorghum production. It is the fifth largest sorghum producer after United States of America, Mexico, Nigeria and Sudan with 5.82 million hectares of area with a total production of 5.39 million tons (FAOSTAT, 2015). Sorghum is tolerant to drought and heat and genetically suited to hot and dry agro-ecologies where it is difficult to grow other food grains. It is important nutrition cereals constituting staple diet of the major population in arid and semi arid region of India. It is also used for feed, fodder and the production of alcoholic beverages. Grain and fodder yield are the principal characters of dual cereal crops. These are complex quantitative characters having positive and negative effects of number of yield contributing traits. They are affected by genetic and environmental factors and thus an interaction between them makes it difficult to select the plant with increased yield. So, the selection for desirable types should not only be based on yield, the other yield components should also be considered. Direct selection for yield is often misleading in sorghum because sorghum grain and fodder yield are controlled by polygenes. For effective utilization of the genetic stock in crop improvement, information of mutual association between yield and yield components is necessary. It is, therefore, necessary to know the correlation of various component characters with yield and among themselves. The correlation coefficients between yield and yield components usually show a complex chain of interacting relationship. Path coefficient analysis partitions the components of correlation coefficient

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into direct and indirect effects and illuminates the relationship in a more meaningful way. The success of a breeding program depends largely upon the amount of genetic variability present in the population and the extent to which the desired traits are heritable. Therefore, an attempt was undertaken to estimate genetic variability, association among desired traits and their direct and indirect effects towards grain and fodder yield of dual sorghum.

MATERIALS AND METHODS

The experiment was conducted at the experimental Farm of the Sorghum Research Station, Sardarkrushinagar Dantiwada Agricultural University, Deesa (BK), Gujarat ((latitude of 24.5° N. longitude of 72° E and elevation of 136 M above the Mean Sea Level)) during *Kharif, 2015*. The experiment consisted of 32 dual sorghum genotypes developed at the centre. The details of study materials are shown in Table 1. The soil of the field was sandy in texture with pH value of 7.5 to 8.00 having good physical and chemical properties (Organic Carbon= 0.23 % , EC = 0.232 dSm^{-1}, K_2O= 259.9 kg/ha and P_2O_5= 46.2 kg/ha). The experimental unit was four-row plot of 5.0 m length with row to row and plant to plant distance maintained at 0.45 and 0.15 meters, respectively. NPK 80:40:00 fertilizers was applied as half basal dose of nitrogen and full dose of phosphorus at the time of sowing and half nitrogen applied after one month of sowing. The all other recommended agronomical practices were followed to raise a good crop during the season. Data were taken on days to 50 % flowering, plant height (cm), number of leaves per plant, leaf length (cm), leaf width (cm), panicle length (cm), grain yield (q/ha) and dry fodder yield (q/ha). Analysis of variance was performed by computer using MSTAT-C software. The test of significance was done by F-test. Genotypic coefficients of variation (GCV) and phenotypic coefficients of variation (PCV) were estimated according to Burton and De Vane (1953); heritability in broad sense (h2b), genetic advance (GA) and genetic advance as % of mean (GAPM) were calculated following Hanson *et.al.*, (1956); correlation coefficients were estimated according to Al-Jibouri *et.al.*, (1958) and path coefficient analysis was done following Dewy and Lu (1959).

RESULTS AND DISCUSSION

Evaluation of 32 advanced genotypes of dual sorghum showed significant differences for the traits viz., days to 50 % flowering, plant height, number of leaves per plant, leaf length, leaf width, panicle length, grain yield and dry fodder yield suggesting the presence of significant variation among the genotypes under study (Table 2). The extent of variability for any character is very important for the improvement of a crop through breeding. The variability of the characters was also measured by Mean, range, GCV, PCV, broad sense heritability (h2b), genetic advance (GA) and genetic advance *per cent* of mean (GAPM) for all traits are given in Table 3.

Table 1 List of 32 sorghum genotypes with their pedigree used in this study

S.N.	Entry	Pedigree	S.N.	Entry	Pedigree
1	DS 0130	IS 22557 x I 12	17	DS 0146	NSSB 15 x NSSB 1005
2	DS 0131	Selection from GJ 39	18	DS 0147	AKR 150 x CS 3541
3	DS 0132	Selection from GJ 39	19	DS 0148	SB 7001 x IS 7528
4	DS 0133	C 43 x ICSR 16	20	DS 0149	IS 22557 x I 12
5	DS 0134	AKR 354 x RS 29	21	DS 0150	CSV 15 x S 35
6	DS 0135	AKR 150 x CS 3541	22	DS 0151	Selection from GJ 39
7	DS 0136	NSSB 15 x NSSB 1005	23	DS 0152	SPV 772 x SPV 1754
8	DS 0137	AKR 150 x CS 3541	24	DS 0153	AKR 150 x CS 3541
9	DS 0138	AKR 150 x CS 3541	25	DS 0154	ICSR 16 x CSV 17
10	DS 0139	SB 7001 x IS 7528	26	DS 0155	SPV 772 x SPV 1754
11	DS 0140	AKR 150 x CS 3541	27	DS 0156	AKR 354 x RS 29
12	DS 0141	IS 22557 x I 12	28	DS 0157	ICSR 16 x CSV 17
13	DS 0142	AKR 354 x SPV 1616	29	DS 0158	SB 7001 x IS 7528
14	DS 0143	IS 22557 x I 12	30	DS 0159	SPV 1616 x(IS 73210xSPV 1428) x I12
15	DS 0144	Selection from SRF 2805	31	GJ 39	M 49 x M 51
16	DSF 0145	SPV 772 x SPV 1754	32	CSV 20	SPV 946 x Kh. 89-246

Table 2 Analysis of variance (mean square) for yield and yield contributing characters in 32 genotypes of sorghum

Characters	Sources of variation		
	Replication (df 2.00)	Treatment (df 31.00)	Error (df 62.00)
Days to 50% flowering	0.85	74.70**	4.92
Days to maturity	6.76	89.97**	4.73
Plant height	343.05	4100.63**	192.44
No of leaves/plant	1.32	2.92**	0.71
Leaf length	18.24	151.48**	4.34
Leaf width	0.19	3.42**	0.63
Panicle length	3.78	96.25**	6.14
Grain yield	90.63*	41.89**	4.70
Fodder yield	1806.26*	2992.66**	492.14

* = significant (at 5% level); ** = highly significant (at1% level), d.f. = degree of freedoms

Table 3 Estimates of genetic parameters for nine characters in sorghum

Parameters	Days to 50%	Days to maturity flowering	Plant height	No of leaves/ plant	Leaf length	Leaf width	Panicle length	Grain yield	Fodder yield
Mean	70.56	102.41	308.66	13.67	88.25	8.25	27.26	19.96	146.80
Range	60.00-79.00	95.00-114.00	234.00-388.00	11.60-16.00	76.20-101.40	6.06-10.60	18.10-38.30	10.70-28.00	83.20-194.20
Heritability (h2b)	82.53	85.72	87.13	50.85	91.87	59.83	83.03	72.53	62.88
GCV	6.84	5.21	11.69	6.27	7.94	11.70	20.10	17.64	19.67
PCV	7.52	5.62	12.53	8.80	8.28	15.13	22.06	20.71	24.80
Genetic advance	9.03	10.17	69.40	1.26	13.83	1.54	10.29	6.18	47.16
GA in % Mean	12.79	9.93	22.49	9.21	15.67	18.64	37.74	30.95	32.13

Among the characters; leaf width, panicle length, grain yield and dry fodder yield displayed more than 15% variation at phenotypic level, which could be considered as high enough. At genotypic level, panicle length, grain yield and dry fodder yield had more than 15% variation and others had less than 15% variation. PCV were slightly higher than GCV indicating presence of environmental influence on the expression of these characters. The high GCV and PCV were recorded for panicle length, grain yield and dry fodder yield but it was moderate for plant height, leaf length, and leaf width. Days to 50% flowering, days to maturity and number of leaves per plant exhibited low genotypic as well as phenotypic coefficient of variation in the present study, which may be due to presence of both positive and negative alleles in the population. The findings were also supported by Amare *et.al.*, (2015) and Chittapur and Birather (2015) who observed high GCV and PCV for grain yield and panicle length. The estimate of GCV and PCV alone is not much helpful in determining the heritable portion. The amount of advance to be expected from selection can be achieved by estimating heritability along with coefficient of variability. Burton (1952) also suggested that heritability estimate would give better information about the efficiency of selection. The study of heritability indicates that the characters leaf length, plant height, days to maturity, panicle length, and days to 50% flowering were highly heritable. Whereas grain yield, fodder yield, leaf width and number of leaves per plant were moderately heritable indicating that the character was more influenced by environment. Although high heritability estimate have been found to be effective in the selection of superior genotypes on the basis of phenotypic performance, Johnson *et.al.*, (1955)

suggested that heritability estimates along with genetic advance will be more useful in predicting the effect for selecting the best individual. The analysis of genetic advance in percentage of mean showed that the characters; plant height, panicle length, grain yield and fodder yield indicated good response to selection. These characters had more than 20% expected genetic advance under selection. Jain and Patel (2014) and Khandelwal *et.al.,* (2015) also reported high genetic advance associated with high heritability for these characters. Days to maturity, days to 50% flowering, number of leaves/plant, leaf length and leaf width had moderate to minimum genetic advance in percentage of mean. These characters had also moderate to low phenotypic and genotypic coefficients of variation indicating that they were less important to selection. Number of leaves/ plant also had low genetic advance associated with medium heritability. Low heritability with low genetic advance for this character was also reported by Khandelwal *et.al.*, (2015). The poor estimates of heritability and genetic advance were due to the influence of environment on this trait. The high heritability estimates along with low genetic advance indicates that non additive type of gene action and genotype-environment interaction plays a significant role in the expression of the traits as observed in days to 50% flowering, Days to maturity and leaf length in the present study. Panicle length, grain yield, dry fodder yield and plant height had high heritability with high genetic advance in percentage of mean making these four characters most important in the selection of dual sorghum. High GCV, PCV, heritability and GA% of mean for panicle length, grain yield and fodder yield suggested that these two characters could be transmitted to the hybrid progeny and phenotypic selection based on these would be effected.

Mutual relationship between grain yield, fodder yield and their contributing characters revealed that in most of the causes the genotypic correlation coefficient was higher than the corresponding phenotypic correlation coefficient indicating strong inherent relation between the traits but suppressing effect of the environment, which modified the phenotypic expression of these characters by reducing phenotypic coefficient values. Such environmental influence in reducing correlation coefficients in sorghum was also reported by Khandelwal *et.al.,* (2015) and Amare *et.al.*, (2015). From the study, grain yield was positively and significantly correlated with panicle length both at genotypic and phenotypic levels. It suggests that grain yield would increase with increase of panicle length. The leaf length and leaf width were also positively correlated with grain yield but the values were non-significant. Among the grain yield contributing characters panicle length had positive and significant interaction with plant height, number of leaves/plant, leaf length and leaf width. Among the studied characters panicle length is the primary yield components and leaf length leaf width, plant height and number of leaves per plant are the most important physiological traits. The fodder yield was positively and significantly correlated with, plant height, number of leaves/plant, leaf length, leaf width and days to maturity. Among the fodder yield contributing traits plant height and number of leaves per plant had positive and significant interaction with leaf length, leaf width and panicle length. The leaf length and leaf width had positive correlation with, days to 50% flowering, days to maturity, number of leaves per plant, plant height and panicle length. This indicated that there is greater relationship between number of leaves with the greater surface area, results in greater photosynthesis that can improve source to sink relationship which lead to improve the fodder yield. Positive relationship between fodder yield and various fodder yield contributing characters were also reported by Alhassan *et.al.,* (2008), Jain *et.al.*, (2011) and Khandelwal *et.al.*, (2015). The study of correlation among seed yield, fodder yield and yield contributing traits suggests that panicle length, plant height, number of leaves/plant, leaf length, leaf width and days to maturity were the most important characters which possessed positive association with grain yield as well as fodder yield. Therefore, these characters could be utilized in breeding program to improve dual purpose sorghum varieties.

Relationship between seed yield, fodder yield and their contributing characters were studied in details through path coefficient analysis. Path coefficient analysis performed to disclose the causes and effects of chain relationships of different yield contributing characters with grain as well as fodder yield. Estimates of direct and indirect effects of yield contributing characters on grain yield using genotypic correlation are presented in Table 5. It was revealed that considerably highest positive direct effect on gain yield was exhibited by fodder yield, panicle length and leaf length. whilst leaf width, plant height, number of leaves per plant, days to 50% flowering and days to maturity had a

Table 4 Estimates of genotypic (r_g) and phenotypic (r_p) correlation coefficients between yield and its contributing characters in sorghum

Parameters		Days to 50% flowering	Days to maturity	Plant height	No of leaves/ plant	Leaf length	Leaf width	Panicle length	Grain yield
Days to maturity	r_g	0.919**							
	r_p	0.749**							
Plant height	r_g	-0.094^{NS}	-0.168^{NS}						
	r_p	-0.034^{NS}	-0.160^{NS}						
No of leaves/plant	r_g	0.089^{NS}	0.194^{NS}	0.249*					
	r_p	0.097^{NS}	0.042^{NS}	0.195^{NS}					
Leaf length	r_g	0.434**	0.402**	0.462**	0.279**				
	r_p	0.381**	0.342**	0.401**	0.219*				
Leaf width	r_g	0.330**	0.457**	0.204*	0.194^{NS}	0.579**			
	r_p	0.265**	0.309**	0.147^{NS}	0.152^{NS}	0.419**			
Panicle length	r_g	-0.086^{NS}	-0.009^{NS}	0.419**	0.219*	0.498**	0.423**		
	r_p	-0.033^{NS}	0.004^{NS}	0.369**	0.112^{NS}	0.454**	0.357**		
Grain yield	r_g	-0.482**	-0.388**	0.011^{NS}	-0.182^{NS}	0.089^{NS}	0.166^{NS}	0.391**	
	r_p	-0.401**	-0.324**	-0.038^{NS}	-0.147^{NS}	0.071^{NS}	0.084^{NS}	0.373**	
Fodder yield	r_g	-0.004^{NS}	0.151^{NS}	0.350**	0.565**	0.275**	0.560**	0.056^{NS}	0.122^{NS}
	r_p	0.094^{NS}	0.120^{NS}	0.220*	0.457**	0.230*	0.388**	0.037^{NS}	0.011^{NS}

* = significant (at 5% level); ** = highly significant (at1% level), NS= no significant.

Table 5 Path coefficient analysis of yield contributing characters on grain yield of sorghum

Parameters	Days to 50% flowering	Days to maturity	Plant height	No of leaves/ plant	Leaf length	Leaf width	Panicle length	Folder yield
Days to 50% flowering	-0.380	-0.147	0.046	-0.045	0.164	-0.071	-0.047	-0.002
Days to maturity	-0.350	-0.160	0.082	-0.099	0.152	-0.098	-0.005	0.089
Plant height	0.036	0.027	-0.489	-0.127	0.175	-0.044	0.227	0.207
No of leaves /plant	-0.034	-0.031	-0.122	-0.512	0.105	-0.042	0.119	0.334
Leaf length	-0.165	-0.064	-0.226	-0.143	0.378	-0.125	0.270	0.162
Leaf width	-0.125	-0.073	-0.100	-0.100	0.219	-0.215	0.230	0.330
Panicle length	0.033	0.001	-0.205	-0.112	0.188	-0.091	0.543	0.033
Fodder yield	0.002	-0.024	-0.171	-0.289	0.104	-0.120	0.031	0.591

Residual are 0.384

Table 6 Path coefficient analysis of yield contributing characters on fodder yield of sorghum

Parameters	Days to 50% flowering	Days to maturity	Plant height	No of leaves/ plant	Leaf length	Leaf width	Panicle length	Grain yield
Days to 50% flowering	-0.435	0.378	-0.040	0.046	-0.055	0.196	0.049	-0.144
Days to maturity	-0.399	0.411	-0.071	0.100	-0.051	0.272	0.005	-0.115
Plant height	0.041	-0.069	0.423	0.129	-0.058	0.121	-0.240	0.003
No of leaves /plant	-0.039	0.080	0.105	0.518	-0.035	0.115	-0.126	-0.054
Leaf length	-0.189	0.165	0.195	0.144	-0.126	0.344	-0.285	0.026
Leaf width	-0.143	0.188	0.086	0.101	-0.073	0.594	-0.243	0.049
Panicle length	0.037	-0.004	0.177	0.114	-0.063	0.251	-0.573	0.116
Grain yield	0.210	-0.160	0.005	-0.094	-0.011	0.099	-0.224	0.298

Residual are 0.194

negative direct effect on grain yield. Khandelwal *et.al.*, (2015) obtained panicle length and dry fodder yield had positive direct effects on grain yield and negative direct effect of plant height, number of leaves per plant, days to 50% flowering and days to maturity. Among the above traits panicle length was highly correlated with grain yield at genotypic level and the direct effects of this character on grain yield could be considered as causes of such high correlation. Fodder yield and leaf length although exhibited high and positive direct effects on grain yield but their correlations with grain yield were minimum. High negative indirect effect of fodder yield and leaf length through plant height and number of leaves per plant reduced the correlation of the character with grain yield to be negligible. The character days to 50% flowering and days to maturity had negative direct effect on grain yield, which suggests that the selection for early maturing lines with high yield is possible.

Estimates of direct and indirect effects of yield contributing characters on fodder yield using genotypic correlation are presented in Table 6. It was revealed that considerably highest positive direct effect on fodder yield was exhibited by leaf width, number of leaves per plant, plant height, and days to maturity and grain yield. Whilst panicle length, days to 50% flowering, and leaf length had a negative direct effect on dry fodder yield of dual sorghum. Among them plant height, number of leaves/plant, leaf length, leaf width and days to maturity were highly correlated characters with dry fodder yield at genotypic level. The direct effects of these characters on dry fodder yield could be considered as causes of such high correlation. These results are in line with Jain *et.al.*, (2009) and Jain *et.al.*, (2010). The residual effect of the present study were 0.384, for grain yield and 0.194 for fodder yield indicating that the characters studied in the present study contributed 62% of the grain yield and 79% for fodder yield. It is suggested that maximum emphasis should be given on the above characters in selecting the dual sorghum varieties. It is also suggested that further study should be made with more characters to find out other traits which contribute rest of the percentage of the grain as well as fodder yield. The characters also showed moderate to high heritability and genetic advance in percentage of mean. Thus, the results suggest that high plant height with higher number of leaves per plant with broaden leaves and long panicle are the important yield contributing traits in dual sorghum and thus plant selection based on these traits will be most effective.

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Exploitation of heterosis for quantitative and qualitative characters in castor (*Ricinus communis* L.)

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ABSTRACT

A study was conducted in Castor (*Ricinus communis* L.) at Castor-Mustard Research Station, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar (Gujarat) to assess the extent of heterosis for ten characters including seed yield per plant. Six lines and Seven testers were crossed in line x tester mating design to develop 42 F_1 hybrids. The analysis of variance was found significant for all the character suggesting the presence of considerable amount of variability among the parents and hybrids for seed yield per plant, important yield components and oil content. A perusal of mean values revealed that the parent SKP 84 had the highest seed yield per plant, whereas among the all hybrids, SKP 84 x SKI 357, SKP 106 x SKI 342 and SKP 42 x SKI 357 registered the highest seed yield per plant. In the present study, extent of heterosis varied from cross to cross for all the traits. The cross JP 96 x SKI 350 recorded the highest heterosis for seed yield per plant (46.18%) over check variety GCH 7 Followed by JP 96 x SKI 342 (35.44%) and SKP 84 x SKI 350 (26.60 %), for 100 seed weight cross SKP 42 x SKI 349 (12.50%) recorded highest heterosis and cross SKP106 x SKI 357 (8.61 %) recorded highest oil content.

Key word: Castor, line x tester, heterosis, seed yield

Castor (*Ricinus communis L.*) with 2n=20 belongs to the family *Euphorbiaceae* and It is indigenous to eastern Africa and most probably originated in Ethiopia. The crop is grown as an important industrial non-edible oil seed crop. India is the world's principle producer of castor and rank first both in area and production. Castor productivity in India is more than world average and it ranks first among the major castor producing countries *viz.*, India, China, Brazil and Thailand. In India, castor crop occupies an area of about 1040 thousand ha with a production of 1733.00 thousand mt and the productivity being 1666 kg/ha (FAOSTAT, 2015). In India castor is being grown for oil under wide ranging environmental conditions.

Commercial exploitation of heterosis in castor is regarded as one of the major breakthrough in the field of castor improvement. Heterosis breeding is an important crop improvement method adopted in many crops all over the world. It is a quick and convenient way of combining desirable characters which has assumed greater significance in the production of F_1 hybrids. In castor, efforts were initiated to exploit heterosis since 1960s even before the identification of pistillate lines. The superiority of hybrids depends on their yield potential over the better released varieties and the extent of heterosis for seed yield and tolerance to biotic and abiotic stresses. Genetic basis of heterosis of seed yield is due to the factors other than heterosis and *per se* performance like the improved parental lines for spike density, more female ratio on spike, earliness, short stature, etc. The heterosis is mainly due to the highly female expression inherited from the dominant female nature of the S type pistillate line(Moshkin, 1986) and contributes to the raise in seed yield. Lack of inbreeding depression on selfing led to the initial slow pace and emphasis on heterosis breeding in castor. The aim of heterosis analysis is to find out best combination of crosses giving high degree of standard heterosis and characterization of hybrids for commercial exploitation.

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MATERIALS AND METHODS

The experimental material for the present investigation were generated by crossing 7 males (Tester) *viz*, SKI 342, SKI 344 , SKI 349 , SKI 350 , SKI 352 , SKI 357 and SH 41 with 6 females (Lines) *viz*, SKP 42, SKP 84 , SKP 106, SKP 121, SKP 122, and JP 96 Crossed during (*kharif - 2014*) in Line x Tester manner were collected from Castor-Mustard Research Station, S. D. Agricultural university. Sardarkrushinagar. The entries (Including parents and F_1 hybrids) were grown during rainy season (*kharif 2015)* at Castor - Mustard Research Station, S. D. Agricultural university. Sardarkrushinagar. Thirteen parents, their hybrids and two checks were raised in a randomized complete block design in two replications. Each genotype was sown in two rows of 6 m length with a spacing of 120 x 60 cm. Recommended agronomic practices were followed to grow a healthy crop. There were six Observations were recorded *viz.*, Length of primary spike (cm), Seed yield (g/plant), 100- seed weight (g), effective spike per plant, Oil content (%), and Number of capsules. The data generated as per Line x Tester model of Kempthorne (1957) were subjected to analysis of variance as per the Line x Tester model given by Singh and Chaudhary (1977)

RESULTS AND DISCUSSION

The results obtained under the present investigation are presented in Table 1 to 2. The analysis of variance was found significant for all the character suggesting the presence of considerable amount of variability among parents and hybrids for seed yield per plant, important yield components and quality characters. The mean square for parents highly significantly for majority of the characters except 100-seed weight, and effective branches per plant revealed that the among parents being significant amount of genetically diversity which is desirable for the heterosis breeding. Mean squares due to hybrids were highly significant for all the characters. Mean square due to female vs. male were highly significant for all the character seed yield per plant, which are mainly yield attributing characters and significantly differ in male & female parents beneficial for high heterosis in hybrids. Mean square due to female was found highly significant for all the characters except 100 seed weight. Mean square due to male was found significant for oil content and seed yield. Comparison of mean squares due to parent vs. hybrids was found highly significant for almost all the characters except 100-seed weight (g) which indicates significant amount variability among parental lines & its hybrids.

In this study, out of forty two, nine hybrids manifested significant positive standard heterosis for seed yield. The cross JP-96 x SKI-350 recorded the highest heterosis (46.18%) over check variety GCH-7 followed by JP 96 x SKI 342 (35.44%) and SKP 84 x SKI 350 (26.60%), while hybrid SKP106 x SH 41 recorded highest relative heterosis (83.75%) and heterobeltiosis (62.53%). High amount of heterosis observed under the present study were agreed with those reported by Sapovadiya *et al.*, (2015), Chaudhary *et al.*, (2015), Patel *et al.*, (2009), Kanwal (2002), Tank (2000), Mehta (1989) and Thakkar (1987) and for heterosis while for heterobeltiosis, Rabadia (1989).

For effective branches per plant, high value of relative

Table 1 Analysis of variance (mean square) for parents and hybrids for seed yield and its component characters

Source of variation	d.f	Length of Primary Spike (cm)	No. Capsule per plant (cm)	Seed yield(g / plant)	100 -seed weight (gm)	Oil Content (%)	Effective Branches/ plant
Replication	1	1292.77***	1748.02***	0.37	20.19	14.49***	4.94**
Parents	12	415.74***	325.73***	1.13***	9.76	21.81***	1.19
Female	5	708.66***	9.645	8.56*	43.65***	0.90	516.035***
Male	6	74.52	5..36	12.15*	5.99***	0.73	152.95
Female Vs. male	1	998.50***	63.15**	1.45	7.52**	5.37**	410.85*
Parents Vs. hybrid	1	296.92*	88.05**	5.44*	0.72	87.01***	374.13*
Hybrids	41	100.74**	16.37**	21.21**	13.50***	2.23***	148.70**
Error	54	49.90	74.12	0.30	8.97	1.00	0.65

* $P \leq 0.05$, ** $P \leq 0.01$.

Table 2 Estimates of per cent heterosis over mid parent (MP), better parent (BP) and check variety (GCH-7) for the characters under study

Sr. No.	Name of Crosses	Test Weight			Oil Content		
		MP	BP	SC	MP	BP	SC
1	SKP 42 x SKI 342	2.73	1.43	0.29	10.65 **	1.31	1.19
2	SKP 42 x SKI 344	2.64	1.94	0.79	10.77 **	0.62	2.28
3	SKP 42 x SKI 349	11.04	8.43	12.50**	9.36 **	-1.56	2.13
4	SKP 42 x SKI 350	0.19	-4.91	-5.97	20.92 **	12.95 **	8.02**
5	SKP 42 x SKI 352	5.3	-2.62	-3.71	14.14 **	3.5	5.62**
6	SKP 42 x SKI 357	-3.76	-4.25	-5.33	11.48 **	-0.67	5.45**
7	SKP 42 x SH 41	12.68	3.71	2.54	13.06 **	2.84	4.23*
8	SKP 84 x SKI 342	3.72	3.49	-0.25	6.6 **	6.16 **	6.93**
9	SKP 84 x SKI 344	-1.69	-2.49	-4.89	-0.01	-0.47	1.17
10	SKP 84 x SKI 349	3.08	-0.81	2.92	0.16	-1.3	2.40
11	SKP 84 x SKI 350	-0.89	-4.58	-8.44	-2.74	-5.19 **	-4.51*
12	SKP 84 x SKI 352	2.28	-4.09	-7.97	0.61	-0.06	2.00
13	SKP 84 x SKI 357	-2.78	-3.73	-5.78	-6.7 **	-9.09 **	-3.49
14	SKP 84 x SH 41	14.74	7.08	2.73	2.77	2.46	3.83
15	SKP106 x SKI 342	-2.36	-4.22	-7.68	-5.05 **	-8.62 **	-1.30
16	SKP106 x SKI 344	-8.66	-10.92	-13.11	-18.11 **	-20.52 **	-14.16**
17	SKP106 x SKI 349	-4.95	-10.02	-6.63	-9.4 **	-11.19 **	-4.08
18	SKP106 x SKI 350	-5.21	-7.21	-13.96	-0.3	-6 **	1.53
19	SKP106 x SKI 352	-6.05	-10.46	-16.98	-4.41 **	-7.04 **	0.40
20	SKP106 x SKI 357	-10.63	-12.99	-14.85	1.43	0.56	8.61**
21	SKP106 x SH 41	3.38	-1.95	-9.11	-3.35*	-6.33 **	1.17
22	SKP121 x SKI 342	1.14	-4.53	-8.00	-2.92	-5.02 **	-0.85
23	SKP121 x SKI 344	2.84	-3.47	-5.84	1.4	0.07	4.47*
24	SKP121 x SKI 349	4.48	-4.68	-1.08	2.32	2	6.47**
25	SKP121 x SKI 350	-5.75	-7.47	-17.84	-1.48	-5.61 **	-1.45
26	SKP121 x SKI 352	7.28	6.31	-9.04	-5.27**	-6.33 **	-2.21
27	SKP121 x SKI 357	-8.26	-14.03	-15.87	-5.21**	-6 **	-0.21
28	SKP121 x SH 41	4.79	3.3	-11.62	2.41	0.91	5.34
29	SKP122 x SKI 342	-12.72	-15.51	-18.57	-2.79	-4.05*	-4.17
30	SKP122 x SKI 344	-3.77	-7.39	-9.68	1.39	-0.79	0.85
31	SKP122 x SKI 349	-51.26**	-54.44**	-6.28	6.7**	3.38	7.25**
32	SKP122 x SKI 350	-12.46	-13.14	-21.64**	-10.62**	-11.37 **	-13.78**
33	SKP122 x SKI 352	-4.35	-7.64	-16.69	-4.07*	-6.32 **	-4.38*
34	SKP122 x SKI 357	-6.3	-9.97	-11.90	-1.55	-5.66 **	0.15
35	SKP 122 x SH 41	1.44	-2.53	-12.09	6.12**	4*	5.40**
36	JP 96 x SKI 342	3.65	-0.21	3.90	1.28	-0.41	2.91
37	JP 96 x SKI 344	-0.06	-3.23	0.76	-1.56	-2.36	0.91
38	JP 96 x SKI 349	4.95	4.77	9.11	0.93	0.73	4.49
39	JP 96 x SKI 350	-0.08	-7.44	-3.62	2.9	-0.93	2.38
40	JP 96 x SKI 352	-2.55	-11.96	-8.31	-4.71**	-5.3**	-2.13
41	JP 96 x SKI 357	-8.79	-11.54	-7.87	-3.11	-4.4*	1.49
42	JP 96 x SH 41	-4.09	-13.76	-10.19	-5.97**	-6.88**	-3.78*
	S.Em±	2.59	2.99	2.99	0.87	1.00	1.00

Cont.

Sr. No	Name of Crosses	Length of Primary Spike			No. of Capsules		
		MP	BP	SC	MP	BP	SC
1	SKP 42 x SKI 342	-10.5	-33.64**	-20.78**	12.8	-13.47	-16.59
2	SKP 42 x SKI 344	-11.6	-31.15**	-17.81	4.36	-12.5	-15.65
3	SKP 42 x SKI 349	17.98	-11.52	5.62	45.92**	11.69	7.67
4	SKP 42 x SKI 350	-24.32*	-47.25**	-37.03**	-12.13	-31.82*	-34.27**
5	SKP 42 x SKI 352	-27.17 **	-41.75**	-30.47**	-34.12**	-36.85*	-39.12**
6	SKP 42 x SKI 357	-27.78 *	-44.37**	-33.59**	-32.05*	-42.86**	-44.91**
7	SKP 42 x SH 41	-28.9 **	-41.88**	-30.63**	-17.71	-27.6	-30.20**
8	SKP 84 x SKI 342	-16.53	-38.06**	-26.25**	-24.05	-44.84**	-37.25**
9	SKP 84 x SKI 344	-26.77 *	-42.91**	-32.03**	-28.32*	-43.6**	-35.84**
10	SKP 84 x SKI 349	-25.7 *	-44.23**	-33.59**	-18.79	-41.13**	-33.02**
11	SKP 84 x SKI 350	-20.6	-44.62**	-34.06**	-20.9	-41.95**	-33.96**
12	SKP 84 x SKI 352	-28.85**	-43.04**	-32.19**	-40.25 **	-46.91**	-39.59**
13	SKP 84 x SKI 357	-27.83*	-44.36**	-33.75**	-22.93	-39.2**	-30.83**
14	SKP 84 x SH 41	-26.06*	-39.5**	-27.97**	-25.19	-38.51**	-30.05**
15	SKP106 x SKI 342	-2.06	-11.57	-36.72**	-3.94	-17.47	-40.85**
16	SKP106 x SKI 344	-14.03	-17.03	-40.63**	-20	-23.58	-45.23**
17	SKP106 x SKI 349	-3.57	-11.57	-36.72**	-0.38	-14.63	-38.81**
18	SKP106 x SKI 350	-2.77	-19.43	-42.34**	-14.54	-25.55	-46.64**
19	SKP106 x SKI 352	0.44	0.44	-28.13**	-9.29	-17.88	-27.39**
20	SKP106 x SKI 357	-9.3	-13.76	-38.28**	-18	-21.4	-43.66**
21	SKP106 x SH 41	-18.56	-20.82	-40.00**	-19.65	-20.51	-41.78**
22	SKP121 x SKI 342	-17.18	-23.86	-47.66**	-14.21	-23.82	-49.45**
23	SKP121 x SKI 344	-3.46	-5	-34.69**	-3.92	-4.72	-36.78**
24	SKP121 x SKI 349	-12.9	-18.64	-44.06**	-12.65	-22.64	-48.67**
25	SKP121 x SKI 350	-2.56	-17.95	-43.59**	-24.08	-31.6	-54.62**
26	SKP121 x SKI 352	5.12	3.06	-26.25**	-15.07	-25.66	-34.27**
27	SKP121 x SKI 357	-10.43	-13.18	-40.31**	-25.12	-25.47	-50.55**
28	SKP121 x SH 41	-11.78	-15.88	-36.25**	-15.25	-19.23	-40.85**
29	SKP122 x SKI 342	2.78	-4.88	-45.16**	-2.85	-11.85	-54.62**
30	SKP122 x SKI 344	10.27	-4.23	-36.25**	17.96	-3.12	-36.78**
31	SKP122 x SKI 349	-1.15	-9.95	-46.25**	-0.5	-9.48	-53.68**
32	SKP122 x SKI 350	-7.64	-9.55	-55.63**	-15.13	-24.12	-59.62**
33	SKP122 x SKI 352	-13.47	-27.07	-47.81**	-27.25	-46.37**	-52.58**
34	SKP122 x SKI 357	9.49	-3.63	-37.81**	13.95	-6.67	-38.65**
35	SKP 122 x SH 41	-11.76	-27.32	-44.84**	-17.93	-35.47	-52.74**
36	JP 96 x SKI 342	-1.24	-8.92	-37.81**	3.24	-9.95	-37.72**
37	JP 96 x SKI 344	16.34	14.87	-21.56**	10.83	7.69	-25.51**
38	JP 96 x SKI 349	6.72	0	-31.72**	21.2	5.43	-27.07**
39	JP 96 x SKI 350	22.49	3.43	-29.38**	7.93	-4.52	-33.96**
40	JP 96 x SKI 352	-13.52	-15.5	-39.53**	-28.6	-36.37*	-43.66**
41	JP 96 x SKI 357	28.24	24.71	-14.84	28.54	25.34	-13.30
42	JP 96 x SH 41	22.78	16.7	-11.56	27.47	23.93	-9.23
	S.Em±	6.12	7.06	7.06	7.45	8.60	8.60

Cont.

Sr. No.	Name of Crosses	No .of effective Spikes			Seed Yield		
		MP	BP	SC	MP	BP	SC
1	SKP 42 x SKI 342	52.54**	40.63**	-15.89**	54.57**	48.05*	25.89**
2	SKP 42 x SKI 344	42.61**	34.43*	-23.36**	-16.95	-21.33	-25.22**
3	SKP 42 x SKI 349	32.28**	15.07	-21.50**	19.3	8.43	-7.82
4	SKP 42 x SKI 350	35.94**	17.57	-18.69**	-5.71	-7.12	-18.61**
5	SKP 42 x SKI 352	52.14**	41.27**	-16.82**	22.66	8.34	20.20**
6	SKP 42 x SKI 357	25.86*	17.74	-31.78**	62.45	27.47	8.39
7	SKP 42 x SH 41	37.5**	18.92	-17.76**	21.34	-4.9	-19.14**
8	SKP 84 x SKI 342	55.36**	35.94**	-18.69**	-6.73	-6.73	-27.40**
9	SKP 84 x SKI 344	37.61**	22.95	-29.91**	2.63	-6.65	-11.28**
10	SKP 84 x SKI 349	25.62*	4.11	-28.97**	39.64	32.18	2.93
11	SKP 84 x SKI 350	54.1**	27.03*	-12.15	52.96**	44.42*	26.60**
12	SKP 84 x SKI 352	15.32	1.59	-40.19**	16.86	-0.56	10.30
13	SKP 84 x SKI 357	47.27**	30.65*	-24.30**	64.84**	33.66	4.09
14	SKP 84 x SH 41	42.62**	17.57	-18.69**	20.9	-2.08	-23.76**
15	SKP106 x SKI 342	25.4*	23.44	-26.17**	67.21*	50.99*	17.58**
16	SKP106 x SKI 344	23.58*	22.58	-28.97**	43.72*	19.3	13.41**
17	SKP106 x SKI 349	15.56	6.85	-27.10**	40.91	34.04	-6.79
18	SKP106 x SKI 350	8.82	0	-30.84**	26.81	8.8	-4.62
19	SKP106 x SKI 352	24.8*	23.81	-27.10**	29.07	1.04	12.08**
20	SKP106 x SKI 357	29.03*	29.03*	-25.23**	55.48*	37.71	-13.59**
21	SKP106 x SH 41	-4.41	-12.16	-39.25**	83.75**	62.53*	2.00
22	SKP121 x SKI 342	8.66	7.81	-35.51**	-7.31	-18.82	-15.90**
23	SKP121 x SKI 344	12.9	11.11	-34.58**	4.23	-0.07	3.55
24	SKP121 x SKI 349	22.06*	13.7	-22.43**	18.08	-1.34	2.22
25	SKP121 x SKI 350	6.57	-1.35	-31.78**	-4.31	-11.68	-8.48
26	SKP121 x SKI 352	14.29	14.29	-32.71**	1.04	-2.29	8.39
27	SKP121 x SKI 357	20	19.05	-29.91**	-18.76	-40.4*	-38.23**
28	SKP121 x SH 41	37.23**	27.03*	-12.15	45.99*	6.99	10.88
29	SKP122 x SKI 342	26.67*	18.75	-28.97**	47.33*	32.38	3.06
30	SKP122 x SKI 344	50.43 **	44.26**	-17.76**	14.13	-5.68	-10.35
31	SKP122 x SKI 349	36.43**	20.55	-17.76**	2.52	-2.99	-32.55**
32	SKP122 x SKI 350	50.77**	32.43**	-8.41	59.11**	35.88	19.09*
33	SKP122 x SKI 352	49.58**	41.27**	-16.82**	3.21	-19.53	-10.75
34	SKP122 x SKI 357	93.22**	83.87**	6.54	53.8*	36.89	-15.05**
35	SKP 122 x SH 41	52.31**	33.78**	-7.48	21.73	8.2	-32.86**
36	JP 96 x SKI 342	53.85**	51.52**	-6.54	34.43*	9.54	35.44**
37	JP 96 x SKI 344	43.31**	37.88**	-14.95	-16.53	-26.18	-8.70
38	JP 96 x SKI 349	26.62*	20.55	-17.76**	-2.63	-23.94	-5.95
39	JP 96 x SKI 350	30.71**	23.65*	-14.02	38.34**	18.2	46.18**
40	JP 96 x SKI 352	55.04**	51.52**	-6.54	-40.26**	-43.33**	-29.93**
41	JP 96 x SKI 357	40.62**	36.36**	-15.89**	-11.02	-38.09**	-23.45**
42	JP 96 x SH 41	32.86**	25.68*	-13.08	-5.74	-34.48*	-18.96**
	S.Em±	0.70	0.81	0.81	0.47	0.55	0.55

heterosis SKP122 x SKI 357 (93.22%), heterobeltiosis (83.87 %) and standard heterosis (6.54%) were recorded. Similar trend was noticed by Thakkar (1987) and Mehta *et al.,* (1989) for heterosis and Thakkar (1987) and Tank (2000) for heterobeltiosis. The highest value for relative heterosis JP 96 x SKI 357 (45.92%), for heterobeltiosis cross JP 96 x SKI 357 (25.34 %) and for economic heterosis cross JP 96 x SKI 357 (7.67%) were recorded for number of capsule per plant. The positive heterotic effects observed under the present study are in correspondence to those of Rabadia (1989) for both heterosis and heterobeltiosis. The heterosis was recorded for 100-seed weight over mid-parent SKP 84 x SH 41 (14.74 %), better parent SKP 42 x SKI 349 (8.43%) and standard check SKP 84 x SH 41 (12.50%) which was similar with those reported by Rabadia (1989), Mehta *et al.,* (1989) for both heterosis and heterobeltiosis,.

For quality character like oil content heterosis was recorded cross over mid-parent SKP 42 x SKI 350 (20.92%), better parent (12.95%), and for standard check SKP106 x SKI 357 (8.61%). The positive desirable heterosis for oil content was earlier noticed by Tank (2000), Kanwal (2002) for heterosis and, Thakkar (2002) and Patel *et al.* (1986) for heterobeltiosis. For length of primary spike highest value of relative heterosis JP 96 x SKI 357 (28.24 %), better parents (24.71%) and standard check SKP 42 x SKI 349 (5.62 %).

In case of heterosis over standard check, number of hybrids exhibited significant heterosis in desired direction for seed yield per plant (9 hybrids), oil content (10 hybrids), and 100 seed weight (1 hybrids). None of the hybrids exhibited significant heterosis in desirable direction for length of primary spike, number of capsules per plant, effective branches per plant. Based on mean performance and heterosis the parents SKP 106 and SKI 350 and the hybrids JP-96 x SKI-350 (46.18%), JP 96 x SKI 342 (35.44%) and SKP 84 x SKI 350 (26.60%), were found to be promising for the development of high yielding genotypes, Thus these results indicated that there will be huge possibilities for genetic improvement and heterosis breeding in castor.

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Bionomics of chiku moth, *Nephopteryx eugraphella* Ragonot (Lepidoptera : Pyralidae) on sapota

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ABSTRACT

Studies on bionomics of chiku moth, *Nephopteryx eugraphella* Ragonot (*Lepidoptera*: Pyralidae) were carried out at Department of Entomology, B. A. College of Agriculture, Anand Agricultural University, Anand during July to September, 2015. The female laid eggs along the midrib on under surface of tender leaves scattered or in batches. The freshly laid eggs were flat, oval in shape having one end broad and other slightly narrow and yellowish white in colour. The average length and breadth of eggs were 0.96 ± 0.02 and 0.46 ± 0.02 mm, respectively. The average incubation period was 3.60 ± 0.49 days. The average hatching percentage was 84.83 ± 6.33. The larva was passed through six instars. The length of first, second, third, fourth, fifth and sixth instar larva was 2.72 ± 0.22, 4.84 ± 0.25, 7.65 ± 0.26, 11.70 ± 0.36, 15.61 ± 0.28 and 20.71 ± 0.52 mm, whereas breadth was 0.47 ± 0.04, 0.80 ± 0.13, 1.46 ± 0.05, 1.73 ± 0.07, 2.09 ± 0.14 and 2.37 ± 0.11 mm, respectively. The width of the head capsule of respective instars was 0.38 ± 0.01, 0.52 ± 0.03, 0.79 ± 0.03, 1.08 ± 0.10, 1.42 ± 0.04 and 1.71 ± 0.04 mm, respectively. The duration of first, second, third, fourth, fifth and sixth instar larva was 3.40 ± 0.78, 5.10 ± 0.84, 4.44 ± 0.64, 3.28 ± 0.46, 3.46 ± 0.50 and 2.80 ± 0.61 days, respectively. The total larval period was 22.48 ± 1.35 days. Fully developed larva suspended feeding, looked sluggish, wrinkled and gradually contract in length and turned into pre-pupal stage. The length and breadth of pre-pupa were 17.33 ± 0.40 and 2.18 + 0.04 mm, respectively. The duration of pre-pupal stage was 1.72 ± 0.45 days. The larvae pupated between webbed leaves. The pupa was light green in colour. The length and breadth of pupal stage were 10.69 ± 0.44 and 2.78 ± 0.15 mm, respectively. The length and breadth of male moth were 17.13 ± 0.75 and 18.81 ± 1.59 mm, respectively. The length and breadth of female moth were 20.25 ± 1.03 and 23.20 ± 1.07 mm, respectively. The pre-oviposition, oviposition and post oviposition periods were 1.57 ± 0.49, 4.05 ± 0.92 and 1.14 ± 0.69 days, respectively. The fecundity of the female was 95.90 ± 14.40 eggs. The sex ratio (male : female) was 1: 1.24 ± 0.36. The total life span for male and female was 34.24 ± 2.20 and 44.18 ± 4.20 days, respectively.

Key word: Bionomics, chiku moth, *Nephopteryx eugraphella*

Sapota [*Manilkara achras* (Mill.) Farsberg, syn. *Achras zapota* Linn.] is an important tropical fruit tree, which is largely grown for commercial purpose in Gujarat, Maharashtra, Karnataka, Tamil Nadu, Kerala, Uttar Pradesh, Haryana, Punjab and West Bengal (Cheema *et al.*, 1954 and Vevai, 1971). In India, the area under sapota is increasing year after year. It was cultivated in 1.77 lakh ha area with a total production of 17.44 lakh tonnes and productivity is 9.90 tonnes/ha (Anonymous, 2014a). In Gujarat, it was grown under 28,800 hectares area with a production of 2.97 lakh tonnes and productivity is 10.4 tonnes/ha (Anonymous, 2014b).

About 25 insect pests attack sapota tree (Butani, 1975). Among these, chiku moth, *Nephopteryx eugraphella* is the more destructive pest of sapota in India. This pest is active throughout the year under Central Gujarat conditions. The newly hatched larvae of *N. eugraphella* infested young terminal, fresh leaves, buds and fruits of sapota. First instar larvae scrapped and fed on green tissues of leaves, whereas later

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instars larvae webbed the few terminal leaves of the shoots and feed on it by remaining inside the web. The pest also attacked on flower, buds and tender fruits which resulted in to premature shedding. The infested plant easily recognized from a distance by presence of numerous webbed brown terminal shoots and dried up clusters of leaves. Considering the economic importance of the pest, its biology and nature of damage were studied along with description of different stages of the pest.

MATERIALS AND METHODS

The biology of *N. eugraphella* on sapota was carried out at Department of Entomology, B. A. College of Agriculture, Anand Agricultural University, Anand during July to September, 2015. The research was carried out at the temperature of 27.71 to 33.40 with an average of 29.71 ± 1.75 °C and relative humidity of 60.14 to 93.84 with an average of 81.11 ± 10.20 per cent in laboratory condition.

Maintenance of culture

Initially, *N. eugraphella* larvae were collected from the unsprayed sapota field and brought to the laboratory. The field collected larvae were kept in plastic container (10 cm diameter and 12 cm height). The container was covered with clean white muslin cloth with the help of rubber bands to prevent the larvae from escaping. Fresh sapota leaves were provided daily to the larvae as a food. After pupation of larvae, pupae were collected in Petri dish which was put in the acrylic rearing cage for emergence of adult. The cage was placed in sun light during morning hours to provide natural condition to the adult. The tender sapota terminal shoots with leaves were wrapped with cotton lint soaked in water at cut end to keep the leaves and fruits fresh and turgid for longer periods. The bouquet of tender shoot prepared as above and held erect in a vial (Diameter: 1.5 cm, Height: 6 cm) was placed inside the cage for egg laying. A swabs of absorbent cotton dipped in 5 per cent honey solution were kept inside the cage as food for adult. The freshly laid eggs were used for details study of bionomics. The measurement of length and breadth was recorded with help of Stereo Zoom microscope and Magnus-Pro software.

RESULTS AND DISCUSSION

Biology of N. eugraphella on sapota

Egg

The female moth of *N. eugraphella* preferred tender leaves and corolla of buds to deposit eggs during night hours only. The eggs were laid scattered as well as in batches along the midrib on under surface of tender leave. Some times, the eggs were laid on the corolla of chiku buds. The freshly laid eggs were flat, oval in shape having one end broad and other slightly narrow and yellowish white in colour. A mobile yellowish embryo could be easily seen under microscope in fertile eggs prior to hatching. At the time of hatching, the colour of the eggs changed to reddish brown. The unfertilized eggs were oval in shape and they were white in colour. The description of the present investigation on eggs are in conformity with the findings of Gupta and Gangarde (1955), Butani (1975), Sran and Sandhu (1989), Patel *et al.* (1988), Patange *et al.* (1996), Patel (1996), Hajare *et al.* (2008) and Shukla and Patel (2011).

The length of eggs ranged from 0.94 to 1.01 mm with an average of 0.96 ± 0.02 mm while breadth varied from 0.43 to 0.53 mm with an average of 0.46 ± 0.02 mm. The data on eggs are in agreement with the report of Patel *et al.* (1988), Patange *et al.* (1996), Patel (1996) and Hajare *et al.* (2008). The incubation period varied from 3 to 4 days with an average of 3.60 + 0.49 days. Results of the present investigation on incubation period of *N. eugraphella* are in close agreement with Gupta and Gangarde (1955), Sran and Sandhu (1989), Patel *et al.* (1987), Patange *et al.* (1996), Patel (1996) and Hajare *et al.* (2008).

In laboratory, the hatching percentage ranged from 66.67 to 95.24 with an average of 84.83 ± 6.33. The present observations on hatching percentage are in accordance with the report of Sran and Sandhu (1989), Patel (1996) and Hajare *et al.* (2008). However, higher hatching percentage (100%) noticed by Gupta and Gangarde (1955) and Patel *et al.* (1988).

Larva

The larvae were found to pass through six instars on sapota leaves in the laboratory. The first instar larva was very active and pale yellowish in colour. The head is brownish and fairly broad. When the larva was viewed under the microscope, the mouth parts were seen fairly prominent with distinct pinkish mandibles. The epicranial suture of head was well seen. The abdomen carries 5 pairs of prolegs on 3rd, 4th, 5th, 6th and 10th abdominal segments. The whole body of larva carries hairs on dorsal side and a set of 3 dorso - lateral pinkish strips on either sides. The length and breadth of the larva ranged from 2.42 to 3.06 mm (Av. 2.72 ± 0.22 mm) and 0.40 to 0.58 mm (Av. 0.47± 0.04 mm), respectively. While, the width of the head capsule ranged from 0.36 to 0.42 mm (Av. 0.38 ± 0.01 mm). The duration of first larval instar was found to

Table 1 Duration of different life stages of *N. eugraphella*

Sr. No.	Life stages	Period (days)		
		Minimum	Maximum	Mean ± SD
1	Egg	3	4	3.60 ± 0.49
	Hatching (%)	66.67	95.24	84.83 ± 6.33
2	Larva			
	I instar	2	4	3.40 ± 0.78
	II instar	4	7	5.10 ± 0.84
	III instar	3	6	4.44 ± 0.64
	IV instar	3	4	3.28 ± 0.46
	V instar	3	4	3.46 ± 0.50
	VI instar	2	4	2.80 ± 0.61
	Total	19	25	22.48 ±1.35
3	Pre-pupa	1	2	1.72 ± 0.45
4	Pupa	7	9	7.28 ± 0.83
5	Adult period			
	Pre-oviposition	1	2	1.57 ± 0.49
	Oviposition	3	5	4.05 ± 0.92
	Post-oviposition	0	2	1.14 ± 0.69
	Longevity			
	Male	5	7	5.84 ± 0.98
	Female	6	8	6.76 ± 0.85
	Fecundity	65	126	95.90 ± 14.40
	Sex ratio	1:0.33	1:1.83	1: 1.24 ± 0.36
6	Total life span: Egg to adult death			
	Male	31	38	34.24 ± 2.20
	Female	35	51	44.18 ± 4.20

Note: SD: Standard Deviation

vary from 2 to 4 days with an average of 3.40 ± 0.78 days. Similar observations were reported by Gupta and Gangarde (1955), Sran and Sandhu (1989), Patel *et al.* (1988), Patange *et al.* (1996), Patel (1996) and Hajare *et al.* (2008).

Second instar larva resembled the first instar in colour and general body form. The second instar larva was comparatively more greenish with light brown longitudinal strips on the body. The thorax carried three pairs of true legs and abdomen carries five pairs of prolegs with faint brown colour head. Similar observations were reported by Gupta and Gangarde (1955), Patel *et al.* (1988), Patange *et al.* (1996), Patel (1996) and Hajare *et al.* (2008). The length, breadth and head capsule width of second instar larva ranged from 4.25 to 5.27 mm (Av. 4.84 + 0.25 mm), 0.60 to 1.24 mm (Av. 0.80 ± 0.13 mm) and 0.48 to 0.56 (Av. 0.52 ± 0.03 mm), respectively. The data on length and width of second instar larva are tally with the finding of Gupta and Gangarde (1955), Patel *et al.* (1988), Patel (1996) and Hajare *et al.* (2008). The duration of second instar larvae varied from 4 to 7 days with an average of 5.10 ± 0.84 days. The duration of second instar larva is closely tally with the report of Patange *et al.* (1996), Patel (1996) and Hajare *et al.* (2008). Patel *et al.* (1988) reported a shorter period (4.27 days) of second instar larva of *N. eugraphella*. However, this contrast might be due to the effect of food and different environmental conditions.

The third instar larva was deep greenish to brownish in colour with black dotted longitudinal strips on either sides and having hairs on body. The mandibles assumed a black colour. The first thoracic segment was brown in colour. Other morphological characteristics were similar to second instar larva. Similar observations were reported by Gupta and Gangarde (1955), Patel *et al.* (1988), Patange *et al.* (1996), Patel (1996) and Hajare *et al.* (2008). The length of third instar larvae was found to vary from 7.11 to 7.95 mm (Av. 7.65 + 0.26 mm), the width from 1.31 to 1.55 mm (Av. 1.46 ± 0.05 mm) and width of head capsule from 0.76 to 0.86 mm (Av. 0.79 ± 0.03 mm). According to Gupta and Gangarde (1955), the length was 7 to 8 mm. While data on width was 1.0 to

Table 2 Measurements of different life stages of *N. eugraphella*

Sr. No.	Life stages	Particulars	Measurement (mm)		
			Minimum	Maximum	Mean ± SD
1	Egg	Length	0.94	1.01	0.96 ± 0.02
		Breadth	0.43	0.53	0.46 ± 0.02
2	Larva				
	I instar	Length	2.42	3.06	2.72 ± 0.22
		Breadth	0.40	0.58	0.47 ± 0.04
		Head capsule width	0.36	0.42	0.38 ± 0.01
	II instar	Length	4.25	5.27	4.84 ± 0.25
		Breadth	0.60	1.24	0.80 ± 0.13
		Head capsule width	0.48	0.56	0.52 ± 0.03
	III instar	Length	7.11	7.95	7.65 ± 0.26
		Breadth	1.31	1.55	1.46 ± 0.05
		Head capsule width	0.76	0.86	0.79 ± 0.03
	IV instar	Length	10.92	12.38	11.70 ± 0.36
		Breadth	1.52	1.86	1.73 ± 0.07
		Head capsule width	0.96	1.36	1.08 ± 0.10
	V instar	Length	15.18	16.10	15.61 ± 0.28
		Breadth	1.81	2.35	2.09 ± 0.14
		Head capsule width	1.37	1.46	1.42 ± 0.04
	VI instar	Length	19.54	21.56	20.71 ± 0.52
		Breadth	2.13	2.54	2.37 ± 0.11
		Head capsule width	1.62	1.82	1.71 ± 0.04
3	Pre-pupa	Length	16.46	18.15	17.33 ± 0.40
		Breadth	2.08	2.27	2.18 ± 0.04
4	Pupa				
	Male	Length	10.00	11.60	10.69 ± 0.44
		Breadth	2.45	3.13	2.78 ± 0.15
	Female	Length	10.52	12.25	11.48 ± 0.39
		Breadth	2.51	3.14	2.83 ± 0.14
5	Adult				
	Male	Length	15.98	18.22	17.13 ± 0.75
		Breadth (wing expanded)	15.11	21.20	18.81 ± 1.59
	Female	Length	18.69	21.74	20.25 ± 1.03
		Breadth (wing expanded)	21.64	24.86	23.20 ± 1.07

Note: SD - Standard Deviation

1.5 mm as reported by Gupta and Gangarde (1955), Patel *et al.* (1988), Gajare (1993), Patange *et al.* (1996) and Hajare *et al.* (2008). Thus, present findings are in confirmly with the results of earlier workers. The duration of third instar larvae varied from 3 to 6 days (Av. 4.44 ± 0.64 days). The larval period of third instar observed in present study was similar to the report of Patel *et al.* (1988), Patel (1996) and Hajare *et al.* (2008).

The fourth instar larva was differed from third instar larva by having the first thoracic segment with a dark brown plate and one pair of black spiracles, second thoracic segment bears two black dorso-lateral spots. The ventral side of larva was greenish in colour and the longitudinal stripes became distinctly visible due to dark brown to blackish colour. The head was lined spotted dark brown. Similar observations were reported by Gupta and Gangarde (1955), Gajare (1993), Patange *et al.* (1996) and Hajare *et al.* (2008). The length and breadth of fourth instar larva were varying from 10.92 to 12.38 mm (Av. 11.70 ± 0.36 mm) and 1.52 to 1.86 mm (Av. 1.73 ± 0.07 mm), respectively, whereas the width of head capsule was varying from 0.96 to 1.36 mm (Av. 1.08 ± 0.10 mm). The present findings on length and breadth of fourth instar are almost in conformity with the reports of Gupta and Gangarde (1955), Gajare (1993) and Patange *et al.* (1996). The width of head capsule are closely tally with result of Patel *et al.* (1988), Gajare (1993), Patel (1996) and Hajare *et al.* (2008). The duration of fourth instar larva varied from 3 to 4 days (Av. 3.28± 0.46 days). The duration of fourth instar recorded during present study are in accordance with the report of Patel *et al.* (1988), Gajare (1993), Patange *et al.*(1996) and Hajare *et al.* (2008).

The fifth instar larva became slightly pinkish in colour with ventral side light green. Larva became stouter and tapering posteriorly. At this stage, the larva was very active and move very rapidly on shoots. The larva having a pair of dark black spot on second thoracic segment. The head becomes green with black brown marks on it. The head and mouth parts were became more prominent. Similar observations were recorded by Gupta and Gangarde (1955), Gajare (1993), Patange *et al.* (1996) and Hajare *et al.* (2008). The length of the larva was found to vary from 15.18 to 16.10 mm (Av. 15.61 ± 0.28 mm). The breadth ranged from 1.81 to 2.35 mm (Av. 2.09± 0.14 mm). The head capsule width ranged from 1.37 to 1.46 mm (Av. 1.42 ± 0.04 mm). Gupta and Gangarde (1955), Gajare (1993), Patange *et al.* (1996) and Hajare *et al.* (2008) had also reported similar length and breadth of fifth instar larva. The width of the head capsule is closely tally with the report of Gajare (1993) and Hajare *et al.* (2008). The duration of the fifth instar larva varied from 3 to 4 days with an average of 3.46 ± 0.50 days. The data on duration are closely tally with Gajare (1993), Patange *et al.* (1996) and Hajare *et al.* (2008).

The sixth instar larva was deep pink in colour. The longitudinal strips became dark black with ventral side to green colour. The prominent hairs were present on dorso lateral side of the body. The full grown larva was very active, moving rapidly on shoots to find out suitable place for pupation. The head was pink brown in colour with black marks on it. Similar observations were recorded by Gupta arid Gangarde (1955), Patel *et al.* (1988), Gajare (1993), Patange *et al.* (1996), Patel (1996) and Hajare *et al.* (2008). The length of the sixth instar larva was found to vary from 19.54 to 21.56 mm (Av. 20.71 ± 0.52 mm). The breadth ranged from 2.13 to 2.54 mm (Av. 2.37 ± 0.11 mm). The head capsule width ranged from 1.62 to 1.82 mm (Av. 1.71± 0.04 mm). Gupta and Gangarde (1955), Gajare (1993), Patange *et al.* (1996) and Hajare *et al.* (2008) had also reported similar length and breadth of sixth instar larva. While Sran and Sandhu (1989), Patel *et al.* (1988) reported more length and breadth of sixth instar larva. This contrast might be due to the effect of food and different environmental conditions. The duration of the sixth instar larvae ranged from 2 to 4 days with an average of 2.80 ± 0.61 days. The data on duration of sixth instar larva are closely tally with Gajare (1993), Patange *et al.* (1996) and Hajare *et al.* (2008).

The total larval period of *N. eugraphella* was ranged from 19 to 25 with an average 22.48 ± 1.35 days. The data on larval period was in close agreement with the finding of Gupta and Gangarde (1955), Gajare (1993), Patange *et al.* (1996) and Hajare *et al.* (2008).

Nature of damage

It was observed under field condition that the larvae of *N. eugraphella* were infesting young terminal, fresh leaves, buds and fruits of sapota. First instar tiny larvae moved about on the leaf surface for some time and then scrapped and fed on green tissues and produced a parchment. After 3 to 4 days, the larvae started to web a few top tender leaves. As the larvae grown, some more leaves were attached to the web so that the web of leaves became larger; the larvae remained inside the webbed leaves and fed voraciously on chlorophyll of leaves leaving behind a papery layer with fine network of veins. Young larvae also attacked the flowers and flower-buds and bore into basal portion

of the buds, which wither and then move on the next bud. The injured flowers and flower-buds dried up and did not bear any fruits. In case of fruits, the larvae fed on small portion and then rejected the fruits. It was also observed the larvae in case, bored into the fruits and consumed the fruit flesh. Infested trees could be easily recognized from a distance by presence of numerous webbed brown terminal shoots and dried up clusters of leaves. The present observations on nature of damage caused by *N. eugraphella* on sapota are in accordance with report of Gupta and Gangarde (1955), Sandhu *et al.* (1974), Butani (1975), Patel *et al.* (1988), Sran and Sandhu (1989), Jhala *et al.* (1993), Patel *et al.* (1993), Patange *et al.* (1996), Patel (1996), Hajare *et al.* (2008) and Shukla and Patel (2011).

Pre-pupa

In the laboratory, it was observed that the fully grown larva was active and move on twig to find suitable place for spinning cocoon of silk and excreta in between two webbed leaves. The larva suspendedits feeding and gradually contracts in length. The colour changes from dark pink to creamy white. The length of pre - pupa ranged from 16.46 to 18.15 mm with an average of 17.33 ± 0.40 mm, while breadth was ranged from 2.08 to 2.27 with an average of 2.18 ± 0.04 mm. Similar observations were reported by Gupta and Gangarde (1955), Sran and Sandhu (1989), Patel *et al.* (1988), Gajare (1993), Patange *et al.* (1996) and Hajare *et al.* (2008). The pre - pupal period was lasted for 1 to 2 days with an average of 1.72 ± 0.45 days. The data on pre - pupal period were in accordance with Gupta and Gangarde (1955), Gajare (1993), Patel (1996), Sran and Sandhu (1989), Patel *et al.* (1988), Gajare (1993), Patange *et al.* (1996) and Hajare *et al.* (2008).

Pupa

In the laboratory, the pupation took place in between two webbed leaves forming cocoon with silk and excreta. The pupa was soft bodied and light green in colour. Gradually, it became hard and changed to reddish brown colour with prominent black eye like spots. The pupae became dark brown prior to emergence of adults. The pupae were long, cylindrical and tapering towards the posterior end. When the pupal period about to over, the adult development was completed and the legs and the wings were clearly visible through the pupal skin under microscope. The pupa which had to develop in to male moth had a slit representing the genital opening in the posterior part of ninth abdominal segment, while in case of female, it was on the eight abdominal segments. The anal apture in both sexes was located on the tenth abdominal segment. Similar observations on colour and shape of pupa were reported by Gupta and Gangarde (1955), Sran and Sandhu (1989), Patel *et al.*, (1988), Gajare (1993), Patange *et al.*, (1996) and Patel *et al.*, (1996).

The length of male pupa ranged from 10.00 to 11.60 mm with an average of 10.69 ± 0.44 mm, while breadth was ranged from 2.45 to 3.13 mm with an average of 2.78 ± 0.15 mm. The length of female pupae was varied from 10.52 to 12.25 mm with an average of 11.48 ± 0.39 mm and breadth varies from 2.51 to 3.14 mm with an average of 2.83 ± 0.14 mm. The data on length and breadth are in close conformity with the report of Gupta and Gangarde (1955), Patange *et al.*, (1996), Sran and Sandhu (1989), Patel *et al.*, (1988), Gajare (1993) and Hajare *et al.*, (2008).

The pupal period was ranged from 7 to 9 days with an average of 7.28 ± 0.83 days. The data on pupal period are tally with the pupal period mentioned by Patel *et al.*, (1988), Gajare (1993), Patange *et al.*, (1996) and Patel (1996).

Adult

The adult of chiku moth was greyish in colour with compound black eyes and setaceous antennae. Forewings were greyish with four black transverse wavy lines. Hind wings were membranous white. Both the wings were fringed at outer margins. A brownish line was present near the outer margins of the wings. The female was slightly bigger than male and with a yellowish brown brush like projection at the tip of abdomen while male having slender abdomen. The observations on morphology and colour of the adults are in accordance with the findings of Gupta and Gangarde (1955), Sran and Sandhu (1989), Patel *et al.*, (1988), Gajare (1993), Patange *et al.*, (1996), Patel (1996) and Hajare *et al.*, (2008).

The length of male adult ranged from 15.98 to 18.22 mm with an average of 17.13± 0.75 mm while breadth was ranged from 15.11 to 21.20 mm with an average of 18.81 ± 1.59 mm. In case of female, the length varied from 18.69 to 21.74 mm (Av. 20.25 ± 1.03 mm) and breadth varied from 21.64 to 24.86 mm (Av. 23.20 ± 1.07 mm).

Gajare (1993) measured the length with wing expanse was about 19 to 20 mm in male and 23 to 25 mm in female. The length of female moth was 10.27 to 11.17 mm and that of male moth was 9.10 to 10.18 mm with the wing expanse of 23.14 to 24.22 mm and 18.18 to 19.91 mm, respectively (Patange *et al.*, 1996).

As per the report of Patel (1996), the length of male and female were 9.24 ± 0.26 mm and 8.14 ± 0.31 mm and width with expanse of wings were 17.90 ± 0.40 mm and 16.34 ± 0.66 mm, respectively. The length of female moth was 17.00 ± 0.81 mm and that of male moth was 20.20 ± 1.03 mm with the breadth of 18.84 ± 1.50 mm and 23.40 ± 1.10 mm, respectively (Hajare *et al.*, 2008). Thus, these reports are more or less similar to present findings.

Pre-oviposition periods

The pre-oviposition period was 1 to 2 days with an average of 1.57± 0.49 days. The pre-oviposition period was vary from a few hours to 2 days (Gupta and Gangarde, 1955); 1.00 to 4 days with average of 1.79 days (Patel *et al.*, 1988); 1.00 to 2.33 days with an average of 1.56 days (Patange *et al.*, 1996); 1.75 ± 0.43 days (Patel, 1996), 1.00 to 2.00 days with an average of 1.40 ± 0.50 days (Hajare *et al.*, 2008). The duration of pre-oviposition period reported by above workers are more or less in agreement with the present findings.

Oviposition periods

The oviposition period varied from 3 to 5 days with an average of 4.05 ± 0.92 days. The oviposition period found in present study is tally with the report of Gupta and Gangarde (1955), Sran and Sandhu (1989), Patel *et al.*, (1988) and Hajare *et al.*, (2008).

Post oviposition periods

The post-oviposition period varied from 0 to 2 days with an average of 1.14 + 0.69 days. The present observation on post-oviposition period is in accordance with the finding of Gupta and Gangarde (1955), Patel (1996) and Hajare *et al.*, (2008), as they reported with range of 0 to 2 with an average 1.15 ± 0.66 days.

Fecundity

The fecundity was varied from 65 to 126 eggs with an average of 95.90 ± 14.40 eggs. Variation in data on fecundity of *N. eugraphella i.e.*, 123 to 214 eggs (Sran and Sandhu, 1989), 4 to 175 eggs (Patel *et al.*, 1988), 118 to 244 eggs with an average of 181 eggs (Patange *et al.*, 1996), an average 32.63 ± 11.66 eggs (Patel, 1996) and an average 97.13 ± 15.14 eggs (Hajare *et al.*, 2008) had been reported by various workers.

The variation in the egg laying capacity of *N. eugraphella* reported by above mentioned workers might be due to the effect of host plants fed to larvae, food given to the adults in the laboratory and other environmental factors.

Longevity

The longevity of mated female ranged from 5 to 7 days (Av. 5.84 ± 0.98 days), while that of male ranged from 6 to 8 days (Av. 6.76 ± 0.85 days).

Thus, the male moth had comparatively shorter life span than female moth. Adult longevity was reported as 3 to 23 days (Gupta and Gangarde, 1955), 8 to 17 days (Sran and Sandhu, 1989). Patel *et al.*, (1988) reported an average longevity of male and female moths was 3.06 and 3.31 days, respectively, while Patange *et al.*, (1996) reported that the longevity of chiku moth varied from 9 to 11 days with an average of 9.76 days. The variation in longevity might be due to difference in weather condition and food provided to the immature stage of this pest.

Sex ratio

In laboratory conditions, male: female ratio was 1:1.24 ± 0.36. Thus, female had preponderance over male in laboratory conditions. The preponderance of females over males of *N. eugraphella* had been reported by Patel *et al.*, (1988), Patel (1996) and Hajare *et al.*, (2008).

Total life period

The total life cycle was found vary from 31 to 38 days (Av. 34.24 ± 2.20 days) in case of male and 35 to 51 days (Av. 44.18 ± 4.20 days) in case of female.

The period of total life cycle was shorter in case of male as compared to female. Similarly, total life cycle of *N. eugraphella* was 26 to 38 days in summer, whereas longer period of total life cycle 45 to 49 days in winter was reported by Gupta and Gangarde (1955), 35 to 39 days (Gajare, 1993), 26 to 92 days (Butani *et al.*, 2002). According to Hajare *et al.*, (2008), the total life cycle of chiku moth was found varied from 36 to 45 days (Av. 39.60 ± 3.21 days) in case of male and 37 to 46 days (40.68 ± 3.10 days) in case of female.

The variation in total life cycle of *N. eugraphella* reported by above mentioned workers might be due to different ecological conditions and nutritional qualities of different cultivar of sapota.

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Susceptibility of wheat cultivars against termite

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ABSTRACT

To know the susceptibility of wheat cultivars against termite, an experiment was carried out at Anand Agricultural University, Anand during *rabi* season of 2010-11. Of the 14 cultivars of wheat screened for their relative susceptibility against termite, cultivars GW 411, Lok-1 and VA-07-13 were found superior to suppressing the termite damage and produced higher yield of grain and straw of wheat. The wheat cultivars GW 407, GW 391, GW 410, GW 273, GW 400 and GW 406 were less susceptible to termite incidence, whereas cultivars Raj-1555, GW 496, GW 396, GW 366 and GW 322 gave poor performance against termite. The evaluated cultivars did not affect the population of termite but prevented them from feeding on root/stem. Less termite population was observed in Raj-1555, whereas it was higher in the Lok-1. There was no detrimental effect of screened wheat cultivars on the number of tillers per plant in wheat.

Key words: Wheat, termite, susceptibility and cultivars

Wheat is second important staple food crop after rice. Its value in human diet, both as a source of carbohydrates and protein, and its baking qualities make it relatively more important crop than other cereal grains. Wheat crop is attacked by 24 species of insect pests (Singh, 1998). Among these, termite is rank first as a pest of wheat not only in India but South Asia too (Geddes and Iles, 1991). About 16 species of termite were found to damage the wheat crop in India, of these two species, *Odontotermes obesus* (Rambur) and *Microtermes obesi* (Holm) were found dominant (Chhillar *et al.*, 2006). The yield losses were recorded 43 to 80 per cent in wheat due to termite damage (Sattar and Salihah 2001 and Chhillar *et al.*, 2006). Considering the importance of the pest, a study was carried out to know the susceptibility of wheat cultivars against termite.

MATERIALS AND METHODS

A field experiment was taken at Anand Agricultural University, Anand during *rabi* season of 2010-11. The wheet crop sown during 1st December 2010 at a distance of 30 cm between rows using different 14 wheat cultivars (Table 1). The gross and net plot area was 4 x 3 m and 3 x 2 m respectively. Different 14 cultivars were screened in a Randomized Block Design replicated three times. For recording observations on termite incidence, infested and healthy plants were counted at weekly interval from 3 m length (each of 1 m) of the net plot area starting from one week of germination till the harvest of the crop. The eucalyptus sticks were installed at a depth of 15 cm in each net plot and termite counts were recorded from the sticks at weekly interval and again reinstalled the sticks. The tillers of different cultivars were also recorded from randomly selected 10 plants from each net plot at 28 days after germination. The grain and straw yield of each cultivar was recorded from net plot area after harvesting and separating the grain. The whole experimental plot was kept free from any pesticide application.

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RESULTS AND DISCUSSION

Tillers

The tiller counts were found non-significant (Table 1), indicates that no detrimental effect of screened wheat cultivars on the number of tillers per plant in wheat. The tillers were observed between 2.40 and 3.60 per

Table 1 Susceptibility of wheat cultivars to termites

Cultivars	No. of tillers/ plant	Termite damaged plants (%)	No. of termites/stick	Yield(kg/ha)	
				Grain	Straw
GW-273	2.47	13.96 (5.82)	6.62 (43.32)	2922.22	3568.89
GW-322	2.80	21.34 (13.24)	6.46 (41.23)	2100.00	2581.67
GW-366	3.20	23.77 (16.25)	6.48 (41.49)	1211.11	1458.33
GW-391	2.87	12.20 (4.47)	6.56 (42.93)	3038.89	3710.00
GW-396	2.73	20.78 (12.59)	6.59 (42.93)	2027.78	2444.44
GW-400	3.37	14.59 (6.35)	6.50 (41.75)	2205.56	2693.89
GW-406	2.40	16.09 (7.68)	6.61 (43.19)	2122.22	2571.94
GW-407	3.13	11.63 (4.06)	6.44 (40.97)	3061.11	3703.61
GW-410	2.83	13.89 (5.76)	6.50 (41.75)	2983.33	3625.28
GW-411	3.60	9.09 (2.50)	6.52 (42.01)	3961.11	4825.56
GW-496	3.40	22.79 (15.00)	6.60 (43.06)	1244.46	1531.39
Lok-1	3.33	9.76 (2.87)	6.67 (43.99)	4083.33	4951.67
Raj-1555	3.13	18.37 (9.93)	6.42 (40.72)	2088.89	2552.22
VA-07-13	3.13	9.97 (3.00)	6.55 (42.40)	3866.67	4676.11
S. Em. ±	0.25	0.72	0.09	255.35	304.20
C. D. at 5%	NS	2.02	NS	742.46	884.48
C. V. %	14.41	9.70	10.03	16.77	16.44

Figures in parentheses are retransformed values; those outside are arcsine value.

plant in the evaluated cultivars. The lowest (2.40) number of tillers was observed in the cultivars GW 406, while it was highest (3.60) in cultivars GW 411.

Termite damage

Fourteen different cultivars of wheat were screened for their relative susceptibility against termite in a field during *rabi* 2010-11. Pooled over period results (Table 1) of termite damage in wheat revealed that the lowest (2.50%) damage was observed in GW 411 and it was at par with Lok-1 (2.87%) and VA-07-13 (3.00%). Wheat cultivars GW 407 was observed equally susceptible to later two cultivars. Wheat cultivars GW

391 (4.47%), GW 410 (5.76%) and GW 273 (5.82%) were equally damaged by termites. cultivars GW 400 (6.35%) was found equally susceptible to later two cultivars but at par with GW 406 (7.68%) in their susceptibility. The termite damage was 9.93 per cent in Raj-1555 and it was significantly less than remaining cultivars. GW 396, GW 322 and GW 496 exhibited termite damage between 12.59 and 15.00 per. Among the evaluated cultivars of wheat, the highest (16.25%) damage was noted in GW 366 and it was at par with GW 496 (15.00%). Godhani and Koshiya (1991) and Shukla (2008) reported that the wheat variety Lok-1 was less susceptible to termites.

Termite population

Termite populations on eucalyptus sticks were recorded after one week of sowing till the harvest of the crop. The termite population were found non significant throughout the study period as well as in pooled over period analysis, indicates that different cultivars not affects the population of termite but cultivars prevents them to feed on root/stem. Pooled over period results (Table 1) revealed that the lower (40.72) termite population was observed in Raj-1555, whereas it was higher (43.99) in the Lok-1. Remaining cultivars of wheat had termite population between 40.97 and 43.32 per stick.

Grain yield

The different cultivars of wheat tested against termites for their susceptibility showed that the higher (4083.33 kg/ha) grain yield was harvested from Lok-1 (Table 1) and it was statistically at par with GW 411 (3961.11 kg/ha) and VA-07-13 (3866.67 kg/ha) and found significantly superior than rest of the cultivars. The cultivars GW 407, GW 391, GW 410 and GW 273 produced 3061.11, 3038.89, 2983.33 and 2922.22 kg/ha grain, respectively. The wheat grain production was statistically equal in cultivars GW 400 (2205.56 kg/ha) and GW 273 (2922.22 kg/ha). The grain yield harvested more or less equal from GW 406 (2122.22 kg/ha), GW 322 (2100 kg/ha), Raj-1555 (2088.89 kg/ha) and GW 396 (2027.78 kg/ha). Among the tested cultivars, the lower (1211.11 kg/ha) grain yield was recorded in GW 366 and it was at par with GW 496 (1244.45 kg/ha). Godhani and Koshiya (1991) and Shukla (2008) reported that the wheat variety Lok-1 was less susceptible to termites and produced higher yield. Satapathy *et al.* (1990) also noticed higher yield of Lok-1.

Straw yield

The higher (4951.67 kg/ha) straw yield (Table 1) was harvested from Lok-1 and it was statistically at par with GW 411 (4825.56 kg/ha) and VA-07-13 (4676.11 kg/ha) and they were significantly superior to rest of the cultivars. The cultivars GW 391, GW 407, GW 410 and GW 273 produced 3710, 3703.61, 3625.28 and 3568.89 kg/ha of straw, respectively. The straw yield was between 2450 and 2700 kg/ha in GW 400, GW 322, GW 406, Raj-1555 and GW 396 and they were at par with each other. Of the evaluated cultivars, the lowest (1458.33 kg/ha) straw yield was noticed in GW 366 and it was at par with GW 496 (1531.39 kg/ha). Godhani and Koshiya (1991) and Shukla (2008) reported that the wheat variety Lok-1 was less susceptible to termites and produced higher yield.

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AMMI analysis of rice yield trials (*Oryza sativa* L.)

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ABSTRACT

Rice (*Oryza sativa* L.) is one of the world's most important staple cereal food crop growing in at least 114 countries under diverse conditions such as irrigated, rainfed lowland, rainfed upland and flood prone ecosystems. The considerable variation in environment has resulted in significant variation in the yield performance of rice genotypes. Thus, genotype x environment interaction (GEI) is an important issue faced by the plant breeders and agronomists. There are different approaches for studying GEI i.e. parametric, non-parametric and multivariate statistical methods. The objective of the present investigation was to analyze the pattern of genotype x environment interaction (GEI) for grain yield of 21 rice genotypes by Additive Main effect and Multiplicative Interaction (AMMI) model using the data generated from the four different locations (Nawagam, Vyara, Dabhoi and Thasra) of Gujarat state, India. The results revealed that the genotypes (G), environments (E) and genotypes x environments interaction (GEI) were highly significant and contributed 7.8, 80.1 and 12.1 per cent of trial variation, respectively. The partitioning of GEI variation into principal component axis indicated that the first two axis were found significant and contributed 63.13 and 27.97 per cent, respectively to the GEI variance. The genotypes *viz.* NWGR-3199 was winner and high yielding for Dabhoi and Thasra locations, IETY-19132 for vyara location and IET-19143 for Nawagam location. Genotypes NWGR-3026, NWGR-3006, IET-19147 and IET-19160 were close to the origin in biplot and hence, they were non-sensitive to environmental interactive forces. Therefore, they possess general adaptation due to better mean grain yield. Nawagam environment was high yielding potential location, whereas Vyara, Dabhoi and Thasra were observed low yielding environments. According to AMMI Stability Value (ASV), $W_{i(AMMI)}$ and $ASTAB_i$, Genotypes NWGR-3026, IET-19147 and NWGR-3006 were found stable whereas genotypes IET-19132 and IET-19143 were unstable.

Key words: Rice, yield, trials

Rice is one of the world's most important staple cereal food crop growing in at least 114 countries under diverse conditions such as irrigated, rainfed lowland, rainfed upland and flood prone ecosystems. The considerable variation due to environment has resulted in significant variation in the yield performance of rice genotypes. Thus, genotype x environment interaction (GEI) is an important issue faced by the plant breeders and agronomists. There are the different approaches for studying GEI i.e. parametric (regression equation) univariate, non-parametric and multivariate statistical methods (AMMI). The analysis of variance is useful for identifying and testing sources of variability, it provides no insight into the particular pattern of the underlying interaction. The ANOVA model effectively describes the main additive effects, while interaction (residuals from the additive model) is non-additive and requires aternatve techniques, such as principal component analysis (PCA) to identify interaction pattern. Thus, ANOVA and PCA models combined to constitute the Additive Main effects and Multiplicative Interaction (AMMI) model (Gauch and Zobel, 1997; Zobel *el al.,* 1988). AMMI is, therefore, a hybrid concept of statistical model incorporating both ANOVA (for additive component) and PCA (for multiplicative component) for analyzing two way genotype x environment data structure. The present investigation was carried out to analyze the pattern of genotype x environment interaction (GEI) for grain yield and to select the stable genotypes of rice. Three stability

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measures (1) $W_{i(AMMI)}$ measure (Raju, 2002) (2) ASV (AMMI Stability Value) proposed by Purchase (1997) and (3) $ASTAB_i$ (AMMI based Selection Index.) (Rao *et al.*, 2004) were also calculated from AMMI analysis to find out stable genotypes.

MATERIALS AND METHODS

Twenty one rice genotypes were evaluated at multilocations (Nawagam, Vyara, Dabhoi and Thasra) of different agro-climatic zones of Gujarat under RBD with three replications. Yield data of rice collected from Main Rice Research Station, Anand Agricultural University, Nawagam were subjected to combined analysis of variance and AMMI model.

Statistical Model :

ANOVA : $Y_{ij} = \mu + \alpha_g + \beta_e + \alpha\beta_{ge} + \rho_{ij} + \varepsilon_{ijk}$

PCA : $Y_{ij} = \mu + \sum_n \lambda_n \gamma_{gn} \delta_{en} + \rho_{ij} + \varepsilon_{ijk}$

AMMI : $Y_{ij} = \mu + \alpha_g + \beta_e + \sum_n \lambda_n \gamma_{gn} \delta_{en} + \rho_{ij} + \varepsilon_{ijk}$

Where

- μ = grand mean
- α_g = deviations of genotype(g)
- β_e = deviations of environment(e)
- λ_n = singular value for Interaction Principal Component Axis n (IPCA)
- γ_{gn} = genotype eigenvector for axis n
- δ_{en} = environment eigenvector
- ρ_{ij} = residual
- ε_{ijk} = error term or uncontrolled variation

The bi-plot is a graphical representation from AMMI analysis which is a useful tool to understand more complex specific pattern of genotypes and GEI or both genotypes and environments. The concept of bi-plot was first developed by Gabriel (1971). It is a scatter plot that graphically displays the genotype (entries) and the environments (testers) of a two-way data and allows visualization of the interrelation among the entries (genotypes) and interaction between entries and testers (environments).

$Wi_{(AMMI)}$

$Wi_{(AMMI)}$ a measure of stability is as good as Wrick's ecovalence (W_i^2) was estimated as per Raju (2002)

$$W_{i(AMMI)} = \sum_{m=1}^{M} \lambda_m^2 \gamma_{mi}^2$$

λ^2_m = singular value for Interaction Principal Component Axis m (IPCA)

γ^2_{mi} = genotype eigenvector for axis n

AMMI Stability Value (ASV)

The AMMI model does not make provision for a quantitative stability measure, such a measure is essential in order to quantify and rank genotypes according their yield stability, the following measure proposed by Purchase (1997) was estimated as under.

$$ASV = \sqrt{\left(\frac{IPCA1\ SS}{IPCA2\ SS} \times (IPCA1\ score)^2\right) + (IPCA2\ score)^2}$$

AMMI based Selection Indices

Rao *et al.* (2004) proposed a new stability measure and incorporated as a stability component. When more than two axis are retained in AMMI model, the biplot formulation of interaction is failed. When n' of N axis are retained in the AMMI model to explain GEI, then the stability measure of i^{th} variety can be determined as the end point of its vector $a'_{1i}, a'_{2i}, \ldots, a'_{ni}$ from the origin $0'_{nx1}$. This is a squared Euclidean distance and was calculated as under.

$$ASTABi = \alpha_{1i}^{2*} + \alpha_{2i}^{2*} + \ldots + \alpha_{ni}^{2*} = \sum_{n=1}^{n'} \alpha_{ni}^{2*} = \sum_{n=1}^{n'} \lambda_n \alpha_{ni}^2$$

A genotype is considered as highly stable when the value of ASTABi is small or closer to zero.

RESULTS AND DISCUSSION

The combined analysis of variance (ANOVA) of 21 rice genotypes over 4 locations according to AMMI model is presented in Table 1.

In AMMI model, additive effects for main effects i. e. genotypes and environments and multiplicative effects for G x E interaction are considered. The results presented in Table 1 indicated that mean square for genotypes and locations (environments) were found significant and highly significant, respectively. This suggested existence of broad range of diversity among genotypes and locations and the differential performance of genotypes over locations i.e. G x E interaction was significant. Of the total treatment

Table 1 Analysis of variance (ANOVA) according to AMMI model for rice genotypes.

Source of Variations	df	Sum of Squares	Mean Squares	F Ratio	% SS
Trials	83	238.2129	2.8700	5.96**	—
Genotypes	20	18.4842	0.9242	1.92*	7.76
Environments	3	190.8184	63.6061	132.01**	80.10
GxE Interaction	60	28.9160	0.4819	5.04**	12.14
PCA I	22	18.2527	0.8297	8.68**	63.13
PCA II	20	8.0882	0.4041	4.23**	27.97
Residual	18	2.5751	0.1431	1.50	8.90
Pooled error	80	7.6496	0.0956		

*. and ** significant at $P < 0.05$ and $P < 0.01$, respectively

variation (trial SS), the proportion of variance due to locations was the largest (80.10 per cent) followed by the variance due to G x E interaction (12.14 per cent) and genotypes (7.76 per cent). ANOVA provided no insight into the particular pattern of genotypes or environments that gave rise to interactions, but described only main effects effectively. These results confirmed to the observations made by Zobel *et al.* (1988). Since G x E interaction was highly significant (Table 1), ANOVA model was combined with PCA model to further analyze the residuals (GEI) of the ANOVA model.

The GEI was highly significant and was further partitioned into two PCA axes (IPCA) which jointly contributed 91.1 per cent of GEI. The first and second PCA were found highly significant ($P < 0.01$) and contributed 63.13 and 27.97 per cent to the total GEI variance, respectively and both the IPCA jointly 91.1 per cent of GEI. The two PC components accounted 70 % of the df for GEI. The residual SS accounted 8.90% of the interaction SS and 30% of df for GEI. (Gauch and Zobel, 1997).

The results of AMMI analysis can also be easily comprehended with the help of AMMI 1 biplot as presented in Fig. 1. The mean performance of genotypes and environments vs IPCA 1 score were used to construct the biplot in Table 2. According to AMMI model, the genotypes which are characterized by mean higher than the grand mean and the IPCA scores nearly zero are considered as generally adapted to all environments. However, the genotypes with high mean performance with large value of IPCA scores are considered to have specific adaptability to the environments (Crossa *et al.* (1991), Sharma *et al.* (1998) and Shinde *et al.* (2002)). Bioplot assay presented in Fig. 1 identified three high yielding genotypes viz., G7, G13 and G14 having general adaptability, having mean yield > 4.336 kg plot^{-1} and close to IPCA 1 = 0 line. Genotypes G10, G12 and G17 were higher yielding and specially adapted to favourable environments. Genotypes G1, G2, G5, G9 and G16 had low mean yield and positioned near to IPCA I = 0 line indicated that they were poorly adapted to all environments.

Similar sign of IPCA I score for both genotypes and environment imply positive interaction and thus it attributed to higher yield of genotype at particular environment (Anandan *et al.*, 2009). Accordingly IPCA scores of genotypes G4, G7, G10, G12, G14 G17, G18 and G20 and of Nawagam (E1) location were positive, which indicated that these genotypes attributed higher yield at this location having positive GEI.

Environments were widely spread over scatter diagram which indicated high variability was among the locations. The environment E1 (Nawagam) was high yielding potential location, whereas, E2, E3, and E4 were found low yielding environments (Mahalingam *et al.*, 2006).

Genotypes located near the plot of origin were less responsive than the vertex genotypes. In this study, genotypes G1 and G14 were close to the origin and hence, they were non-sensitive to environmental interactive forces therefore, have general adaptation with different mean grain yield. Similarly the environment close together i.e. E3 and E4 were found to have similar interaction pattern in genotypes.

Visualization of which-won-where pattern of MLT data is important for studying the possible existence of different mega-environments. The polygon is drawn by connecting the markers of the genotypes that are far away from the biplot origin such that all other genotypes were contained in the polygon. The rays in Figure 2 were lines that were perpendicular to all the sides of the polygon. Ray 1 was perpendicular to the line connecting genotypes G17 and G18. Rays 2

is perpendicular to the line connecting G18 and G5, similar way Ray 3 and 4 were perpendicular to line connecting G5 to G15 and G15 to G17, respectively. These four rays divided the biplot into four sectors and the environments were distributed in the three sectors. The interesting feature of this view of GGE biplot is that the vertex genotype(s) for each sector was/were the best for the environment fall in the same sector than the others in all environments (Yan, 2002). Thus, environment E3 and E4 fell into sector II delineated by Rays 2 and 3 and the vertex genotypes for this sector was G5 suggesting that G5 was the winner high yielding genotype for Dabhoi (E3) and Thasra (E4) locations. Similarly, for environment E2 (sector III) the vertex genotypes was G15 which was the best for Vyara location (E2). Sector IV delineated by Rays 4 and 1 contained the environment E1 and the winning genotypes for Nawagam (E1) location was G17, which was higher yielding genotype. The discrepancy between the results of vertex genotype and higher yielding one may be because of the biplot explained 91.1% to variation of GEI and the remaining 8.90 % variation was unaccounted (Mohammadi *et al.*, 2007).

AMMI Stability Value (ASV)

The ASV is the distance from the co-ordinate point to the origin in two dimensions of IPCA 1 scores against IPCA 2 scores in the AMMI model.

It was weighted by the proportional difference between IPCA 1 and IPCA 2 scores to compensate for the relative contribution of IPCA 1 and IPCA 2 to total GE sum of square. The distance from zero is then determined using the theorem of Pythagoras (Purchase *et al.*, 2000). In ASV method, a genotype with least ASV score was considered as the most stable. Accordingly, genotype G1 followed by G13, G7 and G14 were the most stable, while genotype G15, G17 and G21 were undesirable in terms of stability (Table 3). These results were in confirmation with the results of biplot analysis. Among the stable genotypes, mean yield of all genotypes were higher than over all mean of grain yield except genotype G1.

Table 2 IPCA1 and IPCA2 scores of different rice genotypes and locations.

Sr. No.	Genotypes	Mean yield (kg plot^{-1})	Rank	IPCA1	IPCA2
G1	NWGR-3026	4.165	17	0.036	-0.018
G2	NWGR-3113	4.017	18	-0.073	-0.196
G3	NWGR-3215	3.288	21	-0.197	-0.113
G4	NWGR-3132	4.534	7	0.124	-0.297
G5	NWGR-3199	4.265	16	-0.069	-0.343
G6	NWGR-3213	4.334	11	-0.143	-0.057
G7	NWGR-3006	4.470	8	0.055	0.088
G8	NWGR-2018	4.410	10	-0.160	0.231
G9	NWGR-2032	3.910	19	-0.033	0.275
G10	IET-19140	5.426	1	0.165	-0.184
G11	IET-19148	4.278	15	0.165	0.217
G12	IET-19123	5.351	2	0.092	-0.226
G13	IET-19147	4.634	3	-0.057	0.043
G14	IET-19160	4.579	4	0.079	-0.027
G15	IET-19132	4.327	12	-0.672	0.230
G16	IET-19114	4.322	13	0.022	-0.145
G17	IET-19143	4.574	5	0.464	0.406
G18	IET-19189	4.565	6	0.146	-0.322
G19	IET-19117	4.292	14	0.109	0.347
G20	IET-19146	4.424	9	0.208	0.069
G21	GR-103	3.515	20	-0.260	0.019
	Over all Mean	4.366			
	Environments				
E1	Nawagam	6.922	1	0.837	0.196
E2	Vyara	3.017	4	-0.448	0.722
E3	Dabhoi	3.799	2	-0.089	-0.555
E4	Thasra	3.725	3	-0.301	-0.364

Correlation between PC1 and PC2 = -3.45E-11 ns

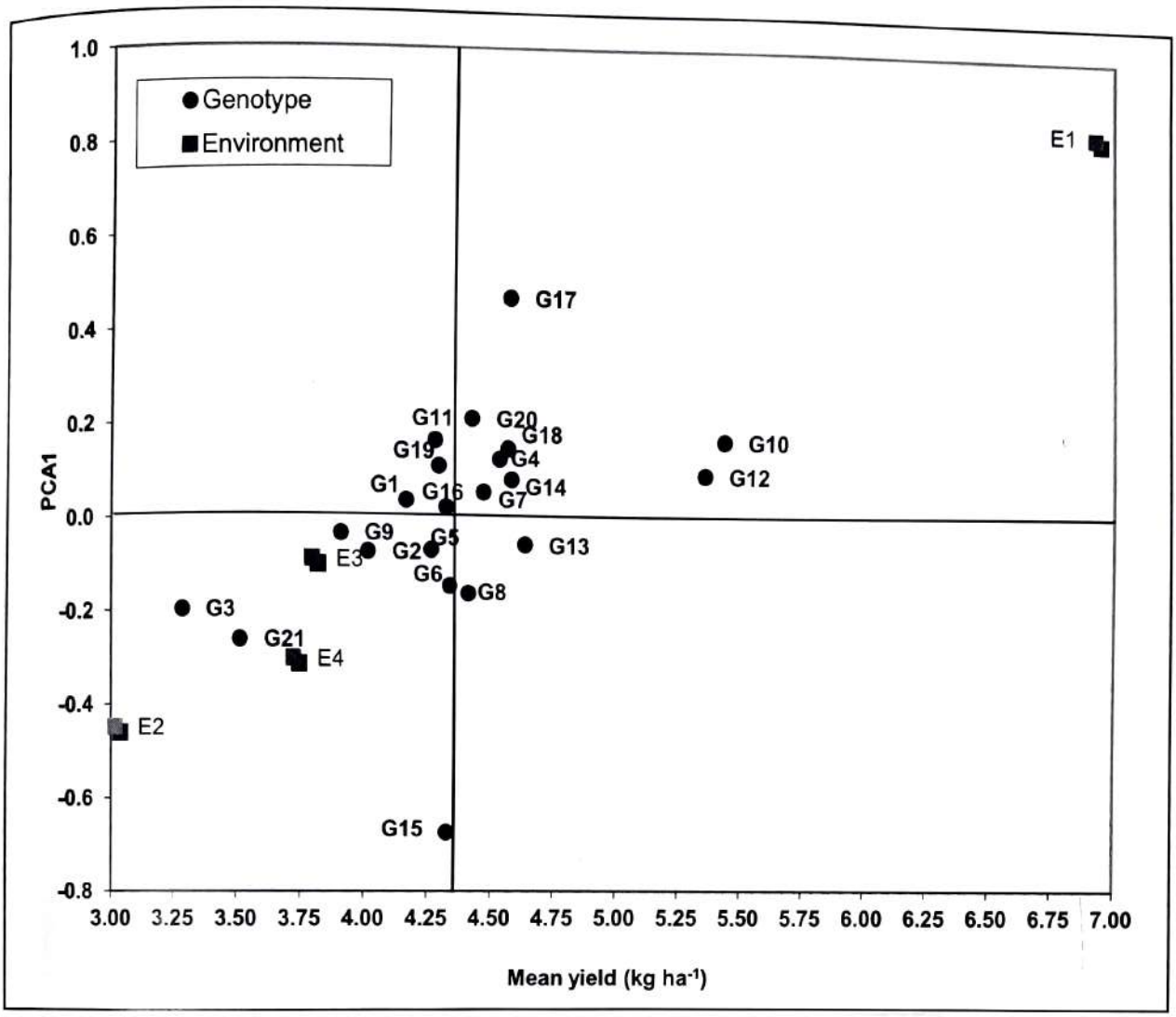

Fig.1 AMMI1 biplot for rice genotypes and locations.

Similarly in unstable genotypes G17 and G21 had higher grain yield while G15 had lower grain yield than mean grain yield (Farshadfar, 2008) This Index (ASV) was also worked out by different researcher to assess stability in different crops (Pourdad, and Mohammadi (2008) and Hugo-Ferney *et al.* (2006)). Thus, present findings are in accordance with those reported by different workers.

$W_{i(AMMI)}$ measure

$W_{i(AMMI)}$, a measure of stability may be viewed as Wricke's ecovalence (Wi^2) in terms of AMMI parameters and may be denoted as $W_{i(AMMI)}$ (Raju, 2002). The different $W_{i(AMMI)}$ values presented in Table 3 indicated that ranks of $W_{i(AMMI)}$ superimposed on ranks of AVS measures. According to the value of $W_{i(AMMI)}$, G1, G13, G7 and G14 were the most stable, while genotype G15, G17 and G21 were most unstable. (Raju and Bhatia, 2003).

AMMI based selection Index (ASTABi)

ASTABi (Rao *et al.*, 2004) stability measures (squared Euclidean distance) were calculated using the retained 'n' axis out of 'N' total axis and presented in Table 3. Genotype G1 had the lowest value of ASTABi followed by G13, G7 and G14 and considered as stable. Among these genotypes, only G1 had lower grain yield than overall mean grain yield. The highest values of ASTABi were observed for G15, G17 and G21 which indicated their unstability over environments.

Thus, overall results suggested that genotypes G 7 (NWGR-3006), G 13 (IET-19147) and G 14 (IET-19160) were high yielding stable genotype which can be recommended for all four locations.

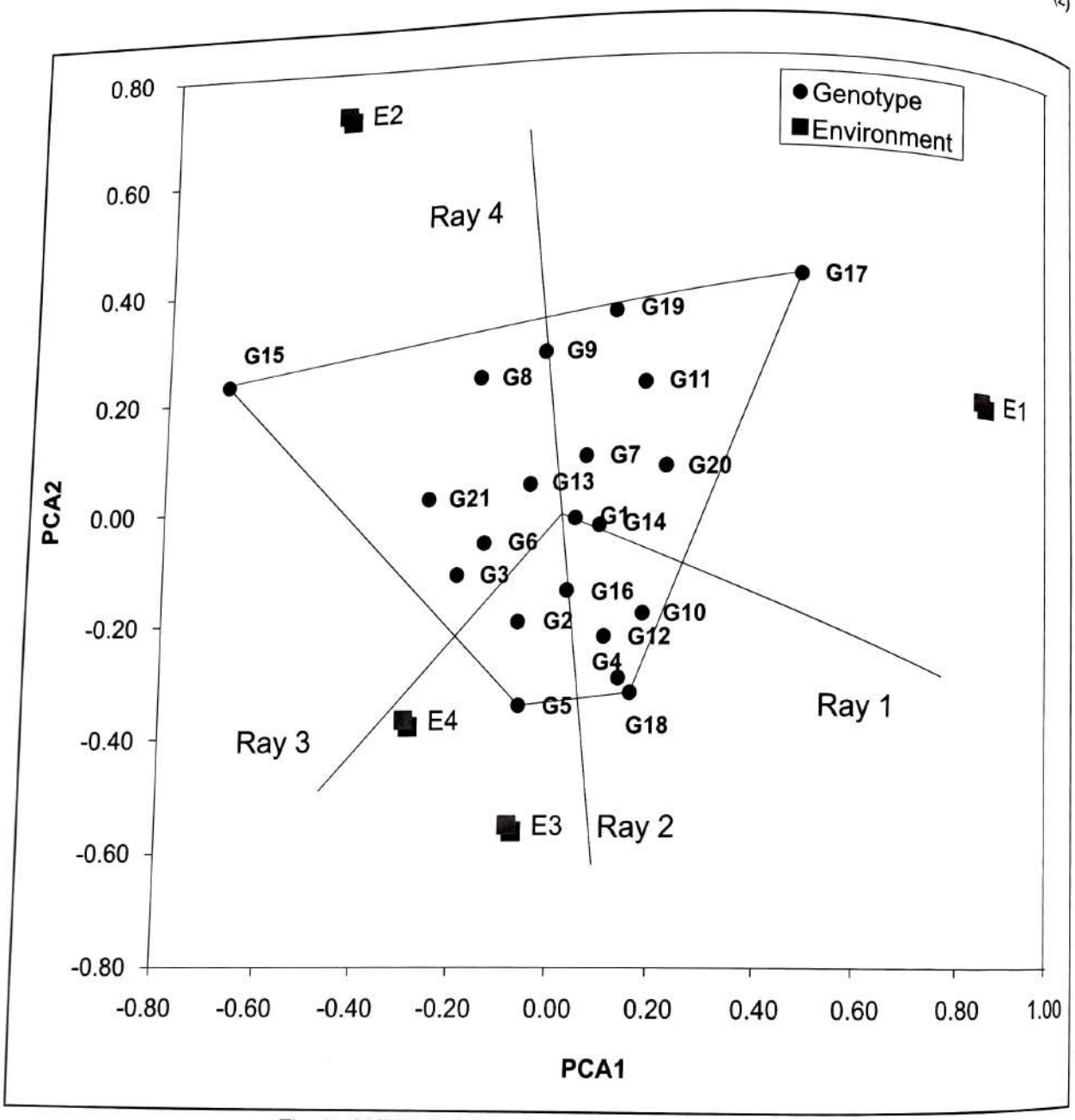

Fig. 2 AMMI2 biplot for rice genotypes and locations

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Table 3 Selection of genotypes based on different indices based on AMMI model for rice genotypes.

Sr.No.	Genotype	Mean yield (kg plot^{-1})	Rank	$W_{i(AMMI)}$	Rank	ASV	Rank	ASTABi	Rank
G1	NWGR-3026	4.165	17	0.026	1	0.056	1	0.03	1
G2	NWGR-3113	4.017	18	0.407	7	0.224	7	0.41	7
G3	NWGR-3215	3.288	21	0.811	11	0.317	11	0.81	11
G4	NWGR-3132	4.534	7	0.996	15	0.351	15	1.00	15
G5	NWGR-3199	4.265	16	1.036	16	0.358	16	1.04	16
G6	NWGR-3213	4.334	11	0.401	6	0.223	6	0.40	6
G7	NWGR-3006	4.470	8	0.118	3	0.121	3	0.12	3
G8	NWGR-2018	4.410	10	0.900	14	0.334	14	0.90	14
G9	NWGR-2032	3.910	19	0.630	9	0.279	9	0.63	9
G10	IET-19140	5.426	1	0.770	10	0.309	10	0.77	10
G11	IET-19148	4.278	15	0.879	13	0.330	13	0.88	13
G12	IET-19123	5.351	2	0.568	8	0.265	8	0.57	8
G13	IET-19147	4.634	3	0.074	2	0.096	2	0.07	2
G14	IET-19160	4.579	4	0.121	4	0.122	4	0.12	4
G15	IET-19132	4.327	12	8.682	21	1.036	21	8.68	21
G16	IET-19114	4.322	13	0.178	5	0.148	5	0.18	5
G17	IET-19143	4.574	5	5.258	20	0.807	20	5.26	20
G18	IET-19189	4.565	6	1.225	18	0.389	18	1.22	18
G19	IET-19117	4.292	14	1.189	17	0.384	17	1.19	17
G20	IET-19146	4.424	9	0.831	12	0.321	12	0.83	12
G21	GR-103	3.515	20	1.235	19	0.391	19	1.24	19

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Plot size study from uniformity trial data of mothbean (*Vigna aconitifolia*)

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ABSTRACT

An uniformity trial on Mothbean crop was carried out at Main Pulses Research Station, S. D. Agricultural University Sardarkrushinagar to find out optimum plot size and number of replications. Maximum curvature method and Fair field Smith variance method were used for this purpose. Based on coefficient of variation (CV) values, a plot of 16 basic units size with shape of 8 rows each of 4.00 meter length (4.00 m.× 3.60 m. = 14.40 m^2) was considered optimum plot size (net plot) with 4 minimum replications for field experiments on mothbean crop at Sardarkrushinagar location (Gujarat).

Key words: variability, plotsize, replications

Agricultural research workers are mainly concerned with field experimentation. Efficient planning of precise field experiments largely depends on adoption of principles of experimental design (Replication, Randomization and Local control), choice of experimental design and suitable size and shape of plot. Each experimental site has an inherent variation i.e. soil variability could be assessed through uniformity trial. The studies of such variation help in proper choice in size and shape of plots and blocks, experimental design and number of replications etc. Such studies based on uniformity trials in Indian conditions were undertaken with various annual crops like Bajra (Patel and Patel, 1967); Paddy (Agrawal and Deshpande, 1967), Tobacco (Prajapati and Patel, 1984), Wheat (Kumar and Singh1986), Mungbean (Singh and Singh, 1989) and mustard (Prajapati *et al.*, 1993). However there is no information on optimum size and shape of plot for mothbean as an important pulse crop of North Gujarat. It is widely used as the main source of protein and calories as well as fodder for animals. The uniformity trial, therefore, was conducted on mothbean crop.

MATERIALS AND METHODS

The popular and high yielding variety Mothbean-3 was sown at a spacing of 45 cm between two rows covering an area of about 0.036 hectare. The other crop cultivation practices in vogue were followed. A block of 20 m. x 18 m. was harvested and seed yield data were recorded separately for 400 basic units. The dimension of each basic unit was three rows of one meter length (0.9 m^2). Border areas were excluded from each side of experimental plot. The different sized plots of size 1, 2, 4, 5, 8, 10, 16, 25 and 40 were formed by combining neighbouring units both length-wise as well as width-wise. The coefficient of variation for different combinations of above sized plots was calculated separately using seed yield data as under

$$C.V.\% = \frac{\text{Standard deviation}}{\text{General Mean}} \times 100$$

The optimum plot size was determined using maximum curvature method (Federer, 1955) and Fair-field Smith's variance law (Smith, 1938). The minimum number of replications (r) and area required for 5 % standard error of mean (S.Em.) for different plot size were calculated as per (Nigam and Gupta, 1997) using the formula as r = (C.V. %)^2 / (5 % SEm)^2. The relative land use efficiency was also calculated for different plot sizes.

RESULTS AND DISCUSSION

The comparisons were made among different sizes and shapes of plots using C.V. % obtained for seed

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yield of mothbean. The results presented in Table 1 revealed that the coefficient of variation (C.V. %) decreased with increase in plot size. The average C.V. % decreased from 21.87 % to to 8.41 % with increase in plot size from 1 unit to 40 units. Initially the decrease in C.V. % was more rapid but after 16 units plot size the reduction was marginal. These results are in agreement with the results reported by Kumar and Singh (1986), Prajapati *et al.*, (1993), Prajapati *et al.*, for bidi tobacco (1984) and Patel and Patel (1967) for Bajra.

The difference between in C.V. % of the consecutive points (plot size) may help to estimate per unit decrease in C.V. % thereby point of maximum curvature. The results are given in Table 2. The per unit decrease in C.V. % (Table 2) was observed from 4.97 % to 0.05 % with increase in plot size from 2 units to 40 units plot size. Further look into the data clearly indicated that the reduction in C.V. was more rapid in the beginning i.e. up to 16 basic units and then it decreased marginally. Thus, reduction in C.V. was not proportional when plot size increased beyond 16 basic units. Therefore, 16 basic units plot size could be taken as point of maximum curvature (Federer 1955) and appeared to be optimum plot size for field experiments on mothbean crop.

The number of replication and required area for different plot size at 5 % standard error of mean were compare from the estimated C.V. % for seed yield of mothbean by using the formula (Nigam and Gupta, 1979). The results are shown in Table 3 revealed that the number of replication and relative land use efficiency decreased as the size of plot increased. Agricultural operation in field experiment with smaller plot size, a

Table 1 C. V. % per unit size for seed yield of mothbean

No. of units	Combinations	C. V. %	Average C.V. % Per unit
1	1x1	21.87	21.87
2	1x2	16.79	16.9
	2x1	17.01	
4	1x4	14.15	13.79
	2x2	13.52	
	4x1	13.70	
5	1x5	13.01	12.28
	5x1	11.55	
8	2x4	11.91	11.67
	4x2	11.43	
10	1x10	11.12	10.45
	2x5	11.19	
	5x2	10.26	
	10x1	9.24	
16	4x4	10.40	10.40
20	2x10	10.09	9.37
	4x5	9.98	
	5x4	9.39	
	10x2	8.00	
25	5x5	9.18	9.18
40	4x10	9.38	8.41
	10x4	7.44	

Table 2 Per unit decrease in C. V % for seed yield of mothbean.

Plot size in basic unit	Average C.V. %	Difference in C.V. %	Per unit decreaseln C.V. %
1	21.87	-	-
2	16.90	4.97	4.970
4	13.79	3.11	1.555
5	12.28	0.91	0.910
8	11.67	0.61	0.203
10	10.45	1.22	0.610
16	10.40	0.05	0.008
20	9.37	1.03	0.258
25	9.18	0.19	0.038
40	8.41	0.77	0.051

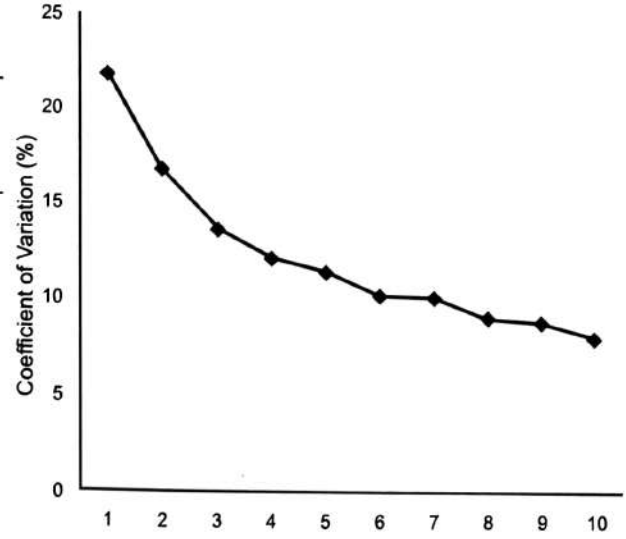

Fig. Coefficient of variation in per cent for different sized plots

Table 3 Number of replications and area required for 5 per cent S. Em. and relative land use efficiency for seed yield with respect to unit plot size.

No. of basic unit plot size	C.V. %	No. of replications	Area required		Relative land use (%) efficiency
			No. of basic units	Sq. m.	
1	21.87	19	19	17.1	100.00
2	16.90	11	22	19.8	86.39
4	13.79	8	32	28.8	59.38
5	12.28	6	30	27.0	63.33
8	11.67	5	40	36.0	47.50
10	10.45	4	40	36.0	47.50
16	10.40	4	64	57.6	29.69
20	9.37	4	80	72.0	23.75
25	9.18	3	75	67.5	25.33
40	8.41	3	120	108.0	15.83

plot size having relatively high land use efficiency with less number of replications should be considered for field experimentation. Such situation was observed with the 16 units plot size which is having considerably less number of replications and relatively high land use efficiency (Table 3) for seed yield. Therefore, 4 replications could be considered optimum for 16 units plot size at 5 % probability level for mothbean crop.

CONCLUSION

A plot of 16 basic units size having shape of 8 rows each of 4 meters length (4 m × 3.6 m) was found as optimum plot size (net plot) with 4 replications for field experiments on mothbean at Main Pulses Research Station, S.D. Agricultural University Sardarkrushinagar.

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Short Communication

Effect of azolla (*Azolla pinnata*) supplementation on performance of gramapriya chickens in rural semi intensive system

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Rural poultry farming in India has transformed into a Techno commercial Industry from status of backyard farming since two decades. Nowadays farmers in TamilNadu tend to go for intensive farming for desi chickens. Rural Backyard Desi chicken farming is low productive mainly due to sub optimal management,lack of supplementary feed, low performance of scavenging attributable to poor feed resource base,and further amount of scavengable feed resource also varies with type of birds due to their forage behaviour, stage of growth and other extrinsic factors such as seasonal variables, levels of predation, health and physiological status of scavenging birds.

Gramapriya is a layer type chicken variety with better adaptability, immunocompetency, better survivability and layingmore number of tinted eggs (150 -160 eggs/yr) than native chickens. The performance of these birds can further be enhanced with minimum supplementary feeding of Azolla, wastegrains, mulberry leaves, drumstic leaves and germinated seeds etc.

Azolla (*Azolla pinnata*) is easily cultivable, productive, nutritive and is the most promising aquatic algal feed(Becerra *et al., 1995*). Azolla is the most economic, easily digestible and efficient feed supplement for livestock and poultry which is rich in protein, essential amino acids, vitamins, growth promoters and minerals etc. (Paoletti *et al.*,1987). Nutrient constitution of azolla is almost identical to that of commercial poultry feed mainly high in protein content. Hence, feeding of azolla to poultry not only improves the health status, weight gain but also increases the productivity in layers, (Kamalasananapillai *et al.*, 2002; Alcantara and Querubin, 1985).

An experiment on effect of Azolla supplementation was conducted in a semi-intensive desi chicken farm size of 500 Gramapriya chicks at Kancheepuram district of Tamilnadu state. Two months old Gramapriya chicks were selected randomly and divided into 4 groups of 25 chicks each in two replicates.

Home-made feed comprising of bajra (40%), ragi (20%), maize (10%), rice (10%),rice bran (14%), ground nut cake(4%), mineral mixture (2%), etc., was prepared and fed as per the recommended feeding regimen fordifferent age groups of birds respectively to sustain the production in semi-intensive system of rearing.The home-made feed preparation costs around ₹ 1 /bird/day.

Hence an attempt was made to reduce feed cost and also to improve the performance of birds in semi-intensive system by supplementing fresh azolla *for* the treatment groupsalong with the regular feed via T_1(Azolla supplement @6.5%/bird/day), T_2 (Azolla supplement @13%/bird/day), and T_3 (Azolla supplement @19.5%/ bird/day), whereas control group was fed only with home-made feed and the birds were let free for 4 hours of for aging /day. As a result of azolla supplementation the cost of feed for the treatment groups drastically reduced to ₹ 0.5 / bird / day.

Data collected for the body weight gain, livability, Feed Conversion Ratio (FCR) and also other traits such as age at first laying ,weight of eggs etc., were tabulated and statistically analyzed as per Snedecor and Cochran (1994).

The mean body weight gain of groups T_2 and T_3 at 12 weeks of age (1.47 ±0.1&1.49± 0.1) and at 16 weeks of age (2.35 ±0.12 &2.29 ± 0.18) recorded were significantly higher ($P<0.01$) than control group(Table 1 and Fig.1) and hence better FCR observed.Similar finding was also reported by Kamalasananapillai *et al.*, (2002) that birds fed with azolla along with regular feed, grew faster, showed increase in their body weight gain.Basak *et al.*, (2002) also opined that supplementing Azolla in the broiler chicken feed had shown better feed conversion ratio.The percent livability recorded at 28th week of age of T_2 and T_3

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Table 1 Effect of azolla supplementation on the performance of gramapriya chickens

Age	Mean ± SD of Body weight (Kgs)			
	Control	T_1	T_2	T_3
8 weeks	0.42±0.2	0.41±0.1	0.43±0.03	0.44±0.3
12 weeks	1.2 ±0.1	1.23±0.09	1.47±0.1*	1.49±0.1*
16 weeks	1.49±0.09	1.5±0.2	2.35±0.12*	2.29±0.18*
	Livability (%)			
28 weeks	96	96	100*	100*
	Mean± SD of Egg weight (gms)			
28 weeks	41±0.8	43±0.7*	50±0.9*	51±0.8*

* Highly significant (P<0.01)

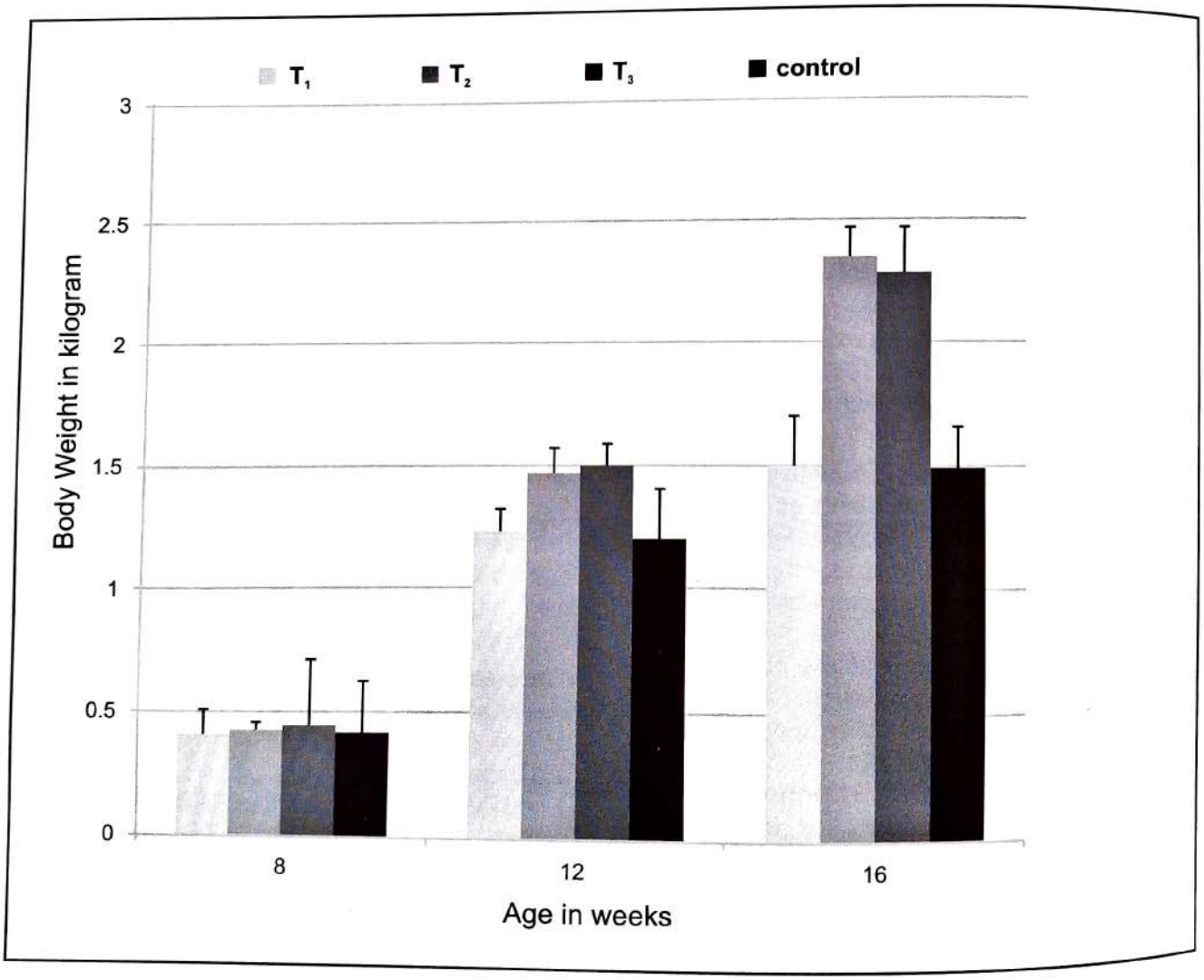

Fig. 1 : Effect of azolla supplement on body weight of gramapriya chickens

groups were also significantly higher ($P<0.01$) compared to control (Table 1). Birds of all groups started its first laying at 160±5 days. However, the mean egg weight(gm)at 28th week of age of all the treatment groups (43±0.7, 50±0.9 and 51±0.8) was significantly superior($P<0.01$) tothat of control group (Table 1).

According to the results obtained from the study it clearly indicated that inclusion of azolla at the levels of 13 % (20gm)and 19.5%(30 gm) in regular home-made feed contributed to the better performance which supported closer to the earlier findings of Alalade and Iyayi's (2006), and moreover economics of azolla supplementation for the treatment groups other than control has proven to reduce the feed cost at around ₹ 0.5 /bird/day.Fresh Azolla could replace about 20% of commercial feed of chickens for better productivity,as already reported by Subudhi and Singh (1978).

This study clearly concludes that azolla can be used as an ideal feed supplement which could be included at the levels of 20-30 gms/day/bird. Appendage of fresh azolla in the regular feed had no deleterious effect on the palatability of chickens and was also cost effective (₹ 0.5-0.6/Kg of Azolla production). Hence supplementing azolla in the regular feed of Gramapriya birds not only improved the performance and was also a boon to reduce the feed cost for a profitable rural semi-intensive chicken farming.

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