International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2015): 78.96 | Impact Factor (2015): 6.391

Exploring Combining Ability to Generate Peasant Farmers Preferred Hybrid Tomato Varieties and Hints on Seed Multiplication

Aromolaran Benserah[1], Prof Zaccarias Russom[2], Prof Samuel Olakojo[3]

[1]Seeds Research Division, National Agricultural Seeds Council, Headquarters, Abuja, Nigeria
[2]Departmentof Crop Production, Faculty of Agricultural Technology, Abubakar Tafawa Balewa University (ATBU), Bauchi, Nigeria
[3]Department of Maize Improvement, Institute of Agricultural Research and Training (IAR&T), Moor Plantation, Ibadan, Nigeria

Abstract: ***Hybrid tomato production is a rare adventure in many developing countries; also while many believe that more than enough quantity of tomato is annually produced; little or no cognisance is taken that farmers are compelled to grow only the readily available materials. For cultural and economic returns, peasant farmers prefer the indeterminate tomatoes. This experiment was carried out at Abubakar Tafawa Belewa University Farm (ATBU), Bauchi; in the northern Guinea savannah. In the experiment, different crosses using five varieties of tomato were made. Seeds of the five tomato parents and F_1 plants of the six crosses making eleven genotypes were sown in the field in a randomized complete block design (RCBD) with two replications. The following were observed: (i) heterosis/dominance expressed in the crosses that involved determinate x indeterminate in favour of fruit plant-^{1} and of seed fruit-^{1} (ii) cytoplasmic gene expression. Therefore more elaborate and extensive trials are required to ensure that tomato seed security receives needed attention.***

Keyword: Tomato hybrid, combining ability, seed-security, economic returns

1. Introduction

Although tomato (*Lycopersiconlycopersicum (*formerly *Lycopersiconesculentum)* is a household vegetable among culinary crops; it is credited for higher nutritional benefits several times more than the nutritional benefits of the apple fruits (Francis J.F (2010). There are three types of tomatoes (determinate, indeterminate and semi-determinate) each produce suckers. Determinate tomato vines, like Roma VF, reach their mature size before blooming and setting fruit. Their fruits are ripened all at once and then the plant starts to die back. Suckers on determinate plants have less of an effect on fruit production because of the bushy growth pattern and short fruiting season.

On the other hand, traditional sprawling home garden tomatoes, like Early Girl, Derica are indeterminate. They grow continuously from sprouting till first frost, covering a large area with sucker-produced branches. Fruit is produced over the whole season rather than all at once and is more affected by sucker growth. The more suckers you let develop, the later in the season tomatoes will ripen, since sugar is diverted to growing leaves and stems. You may get more tomatoes.

According to Pnueli (1998), the tomato stem portions that are repetitively produced after each new inflorescence are called the sympodial segments. The self-pruning gene (SP) regulates sympodial development by controlling the regularity of the vegetative–reproductive switch of the different sympodial segments. The sp mutant is determinate: the number of vegetative nodes arising on successive sympodial shoots is gradually reduced until the vegetative phase is bypassed completely with the production of two successive inflorescences. Determinate tomatoes are used mainly by the food processing industry. This was most likely to have been the invention of breeder rather than an outcome of natural mutation.

Between these two tomato extremes are the semi-determinate types, like Mountain Fresh Plus. Their growth habit is sympodial like the indeterminate types. They have suckers but not as many and the vine is less vigorous than the indeterminate type.Francis J Ferrandino (2010).

According to Dielen*et al* (2004) the uniflora (UF) gene regulates time to flowering and inflorescence meristem identity in tomato; while flowering time in the mutant uf is season-dependent, it is particularly delayed when the daily light energy integral is low. The uf mutant produces solitary, normal, fertile flowers instead of inflorescences and always flowers later than the wild type, the late-flowering character being observed in both the initial and the sympodial segments. In these conditions, plants develop strong lateral branches at node levels where normally the wild-type plant initiates inflorescences, suggesting that they undergo a partial evocation at this level but are unable to complete the process. This corroborates Rick (1976) speculation that the indeterminate pattern of plant development responsible for yield and its components was due to two major gene systems: genes that determine morphogenetic responses and genes that determine growth rate manifestations. Thus inference from the report of Penueli*et al* (1998) implies that the two genes are the self-pruning (SP) and uniflora (UF) genes respectively.

From the review of literature so far, it appears not many workers have appreciated the fact that in sub-Sahara Africa over 80 percent of the people that engaged in agriculture are peasants; therefore these farm-families prefer such varieties that provide economic returns for a longer period of time and as well adapted to traditional cultural practices –mixed cropping. Adaptation to climate

change is also a priority consideration among the elites that are recently going into commercial agricultural production as well as those emerging seed producer companies. However, the situation at hand constricts farmers to grow only the available materials at the time of planting; this denies the simple definition of seed security by Sperling and Cooper (2003) that seed security: is availability of seed of preferred crop variety at affordable price in a given community at the time of need; they went further to state that 'seed availability' refers to whether a sufficient quantity of seed of appropriate crops is present physically within reasonable proximity, and in time for planting. But while most farmers prefer indeterminate tomato varieties which often not available in quantity required, they have to make use of any available material or fall-back to farmers' saved-seeds. This is largely due to the fact that indeterminate tomato guarantees steady flow of supply to the market for longer period of time, which directly translates to better economic returns rather than one heavy slot (peculiar to determinate varieties) that often constitutes glut at the paucity of industrial capacity to take them up for processing or storage that could help sustain stable-pricing.

Therefore, there is no doubt that these factors will continue to popularise indeterminate/semi-determinate varieties in most of the developing countries towards meeting these socio-economic preferences; as opposed to what is obtained in the developed economies that operate fully mechanized farming-system which is much more suited to determinate varieties production. For some time to come sub-Sahara African States will remain catchment area for high-yieldingindeterminate tomato varieties cultivation; thus form the thrust of this trial in order to satisfy this endemic demand and the underlying seed security which may not be obvious to several workers and a non-issue to breeders especially in the developed economies.

2. Materials and Methods

Four tomato varieties: Roma VF, Polypark, Dukado and Ronita; were obtained from the Bauchi State Agricultural Development Project- Agro Supply Unit; while Derica a popular cultivar was collected from a local farmer in Bauchi. The characteristics of each of the five tomato varieties are presented in Table 1.

Table 1: Some characteristics of the tomato varieties used

Variety	Fruit shape	Fruit size	Growth Habit
Roma VF	Pear Shape	Small	Determinate
Polypak	Flattened globe	Big	Indeterminate
Derica	Sweet pepper shape	Very big	Indeterminate
Dukado	Pawpaw shape	Medium	Determinate
Ronita	Oval	Medium	Determinate

At flowering, flower buds were emasculated about a day prior to pollen grains maturity. The forceps which were used to emasculate were frequently immersed in a methylated spirit in order to kill any unwanted pollen and to avoid contamination. The emasculated flowers were covered with paper bags

The following morning, mature pollen grains from the desired parents were carefully collected and dusted on the stigma of the emasculated flowers previous day. They were labeled with names of the female and male parents; and the pollinated stigmas were kept covered. The following crosses were then made among the five tomato varieties:

Roma x Polypark, Polypark x Roma, Derica x Dukado, Dukado x Derica, Dukado x Roma, Roma x Dukado and Ronita x Roma.

On the average, 75 crosses were made for each of the six cross combinations. Seeds from each randomly selected from F_1 fruits were extracted. A total of 50 seeds from each crosses were raised in a nursery tray. Similarly, 50 seeds were raised from each parent. Their seedlings were transplanted to the field when they were four weeks old at the ATBU Research farm. The spacing was 60x 90 cm for all genotypes with 120 cm path between plots at 21 stands per plot. The five parents and the six hybrids were replicated twice using randomized complete block design.

The following data were collected: number of flowers emasculated, number of flowers pollinated, number of each aborted flowers, number of flowers with fruits set or success, number of seeds per fruit, for each cross. For F_1, number of emerged seeds (seedlings), number of days to seed emergence, growth habit and fruit shape.

3. Results

Zygotes abortion:

On the average, there were 75 pollinated flowers in each cross. Ronita x Roma had the highest number of aborted zygote and Polypark x Roma had the lowest number of aborted zygote (Table 2); while Derica x Dukado had the lowest of fruit set. [Note: during crosses, besides fruit set and abortion, there are possibilities for voids (ie, crosses that did not set at all] It was noted that the reciprocal of Ronita x Roma, which is Roma x Ronita had lower number of fruit set. Table 2, also shows that flower abortion varied from 32 (Polypark x Roma) to 48 (Derica x Dukado), while percentage of fruit set ranged from 10% (DericaxDukado) and 18% (Ronita x Roma).

Among the tomato crosses, Ronita x Roma VF had the highest number of aborted zygotes.However, the abortion rate observed might be attributed to physiological rather than genic factor. Sawhey and Dabbs (1978) reported that seed contains auxin, which promotes fruit growth; and its formation is correlated with fruit growth rate in tomato. Rather than often, fewer quantity of pollen were involved in artificial crosses especially in this kind of a student experiment, thus the amount of pollen involved perhaps could not generate satisfactory quantity of hormones required for normal fruit development; hence abortion of such fruits became inevitable. Furthermore, Gladis*et al.*(1986) pointed out the influence of morphognetic

variation within individual plant, within raceme (a truss) of flowers and among cultivars of tomato determine success of pollination and fruit setting. Even at intervarietal

Table 2: Number of flowers emasculated and pollinated, number of flowers aborted and number of flowers with level pollination and fruit setting may fail, due to secretion of biochemical substances that prevent growth of pollen tube (Olakojo, 2005)

Genotypes F_1	Number of flowers Emasculated and Pollinated	Number of flowers Aborted	Number of flowers with Percentage of fruit Set
Roma x Polypark	75	40	15
Polypark x Roma	75	32	16
Derica x Dukado	75	48	10
Dukado x Derica	75	35	12
Ronita x Roma	75	51	18
Roma x Ronita	75	51	17

For commercial seed production one should know the fact that Naphthalic Acetic Acid (NAA) is synthetic auxin and it is known to stimulate cell division, cell elongation, elongation of shoot, photosynthesis, RNA synthesis membrane permeability and water uptake also involved in many physiological processes like prevention of pre-harvest fruit drop, flower induction, fruit set, delayed senescence and prevention of bud sprouting etc. Similar report was observed by Revanappa (1993) who obtained the highest average fruit weight (2.60 g), fruit girth (14.9 cm), number of fruits per plant (139.29), number of seeds per fruit (95.49), fruit yield per plant (395.07 g) and yield per ha (95.9 q/ha) in NAA 20 ppm sprayed treatment compared to control (2.20g, 12.6 cm, 118.40, 1322.84g and 79.30 q/ha respectively) in chilli.

Nevertheless, we suggest that for commercial seed production much pollen should be used to pollinate in ratio 4:1 of stigma to pollen flower.

Growth pattern among F_1tomato

Number of F_1 plants observed among the different parents having different growth habit is presented in Table 3. The result clearly showed that all crosses involving determinate crossed with indeterminate gave indeterminate F_1 plants, and crosses involving determinate crossed with determinate gave determinate F_1 plants including their reciprocal crosses.

Table 3: Growth habit found among theF_1 plants.

Genotypes F_1	Determinate	Indeterminate
Roma (Determinate) x Polypark (Indeterminate)	0	35
Polypark (Indeterminate) x Roma (Determinate)	0	35
Derica (Indeterminate) x Dukado (Determinate)	0	35
Dukado (Determinate) x Derica (Indeterminate)	0	35
Ronita (Determinate) x Derica (Indeterminate)	35	0
Roma (Determinate) x Ronita (Determinate)	35	0

For instance, Roma x Ronita which is determinate crossed with another determinate, they gave determinate F_1 plants; while determinate x indeterminate (Roma VF x Polypak) and their reciprocal produced indetermin*ate* growth habit. According to Pnueli *et al (1998)* determinate growth habit is mediated by sp a mutant allele to self-pruning (SP) when in homozygous state, this regulates sympodial development by controlling the regularity of the vegetative–reproductive switch of the different sympodial segments. This sp mutant unambiguously demonstrated homozygous recessiveness in this trial except for when indeterminate (Derica) sired determinate (Ronita). There is no doubt that this is a novel observation; but could this be pointing to cytoplasmic effect? This may not hold in all cases; therefore to achieve the very objective of the work, which aimed at obtaining high-yielding indeterminate hybrid varieties; prior-testingof parental-lines for the purposed is suggested. More so, the uniflora (UF) gene regulates time to flowering and inflorescence meristem identity in tomato; while flowering time in the mutant uf is season-dependent, it is particularly delayed when the daily light energy integral is low. The uf mutant produces solitary, normal, fertile flowers instead of inflorescences and always flowers later than the wild type, the late-flowering character being observed in both the initial and the sympodial segments. In these conditions, plants develop strong lateral branches at node levels where normally the wild-type plant initiates inflorescences, suggesting that they undergo a partial evocation at this level but are unable to complete the process (Dielen*et al*., 2004).

F_1 comparative performance with parental lines

Table 4a (below) presents mean square for number of fruit $-^1$ and seeds fruit $-^1$ for the 11 genotypes; that is the five parents and six F_1s. With respects to this two parameters; it was observed that the differences in the performance of the genotypes were highly ($P<0.01$) significant. On the other hand, means separation for the 11 genotypes in Table 4b shows that fruits plant^{-1} among the parents varied from 60.5 (Polypak) to 100.5 (Derica); while the means among the F_1 ranged between 57.0 (Polypak x Roma) to 191.0 (Dukado x Derica), a good signature of heterosis.

Table 4a: Table of means square for number of fruits plant^{-1} and number of seeds fruits (tomato)

S.V	D.F	Fruit Plan-MS	Seeds/Frui-MS
Rep	1	1237.5	11.63
Genotype	10	2942	1336.10
Error	10	229.6	13997.09
Total	21		

****Significant at P<0.01**

From table 4b below, it appears that the low number of fruit set in the Ronita x Roma and Roma x Ronita could be seen as self-initiated repulsion to discourage further inbreeding attempted or assertion of (recessive)

homozygousity. Also, Dukado x Derica F_1 gave the highest number of fruit per plant and the reciprocal Derica x Dukado yielded highest number of seed per fruit. It is interesting to recall that while Derica is local cultivar in Bauchi, Nigeria; Dukado is among the exotic varieties being introduced into the country. It was commonly assumed that hybrids produced from lines having different origin (i.e. developed from different cultivars) tended to have greater, consistent yield levels than hybrids of inbred lines originating from the same source population.

Furthermore, Falconer (1989) observed that the concept of heterotic groups gradually evolved from empirical evidence of crosses from inbred lines. Theoretically, the more distant the parents, the greater is the number of genes they differ, thereby the greater the potential interaction of the genes in the form of dominance and epistasis, and the greater will be potential for heterosis. In this sense genetic diversity might be an important issue in predicting F_1 performance. The assignment of tomato lines to heterotic groups before field testing may allow the breeder to avoid crosses within groups that would result in lower returns.

Genetic diversity can be measured by several means including pedigree data, genotypic origin from contrasting geographic regions, etc. although molecular methodologies are considered as the most reliable ones. The latter might contribute to increasing the accuracy in determining the divergence between the genotypes of interest, which could ultimately lead to improved classification. Comparison of molecular markers with pedigree data of related genotypes, based on theoretical and experimental results is however, recommended (Melchinger 1993). The idea of exploiting the genetic distance of the parents as an indicator in the pursuit of heterosis in tomato hybrids is not a new one. Daskaloff (1942) reported high level of heterosis for yield and earliness in F_1 between tomato lines developed on the basis of hybridization between the tomato cultivar Sarya and L. racemigerum (Lange) (accession unknown), lately classified by Muller (Zhutchenko 1973) as L. pimpinellifolium Mill. It was also reported that lines developed on the basis of interspecific hybridizations were characterized by high combining-ability of economically important traits. Based on these findings it

Table 4b: Effect of genotype on number of fruits plant^{-1} and number of seeds fruits^{-1} of the F_1

Genotype	Number of Fruits Plant^{-1}	Seed fruit^{-1}
Parents		
1. Roma VF	80.50^{c}	71.0^{d}
2. Polypark	60.54^{d}	133.0^{b}
3. Derica	100.54^{cd}	122.0^{b}
4. Dukado	75.00^{cd}	97.0^{b}
5. Ronita	80.0cd	97.0^{c}
F_1		
6. Roma x Polypark	135.0^{b}	85.0^{cd}
7. Polypark x Roma	57.0^{b}	132.0^{b}
8. Derica x Dukado	110.0^{bc}	155.0^{a}
9. Dukado x Derica	191.0^{a}	92.0^{c}
10. Ronita x Roma	83.0^{cd}	86.0^{cd}
11. Roma x Ronita	88.0^{cd}	82.03^{cd}
Mean	96.40	105.63
CV(%)	15.71	7.48

For each character, means follow by the same letter are not significantly different, using DMRT was concluded that for acquiring heterosis for early and total yield, the hybrids should include lines of different origins (Yordanov 1983).

Although, it is commonly assumed that genetic stability (homeostasis) in hybrids refers to reduced genotype-environment interaction; but Yordanov (1983), Russel et al (1983), Cooper and Podlich (1999), Temperini et al (2001) remarked that a number of studies provided evidence that the majority of quantitative traits were significantly affected by environmental factors and that heterosis was also dependent on the environment therefore the evaluation often given tomato hybrid when grown in different locations is necessary for getting reliable information on its performance; thus affirms the fundamental concept of gene-environment dynamics on yield-index. This kind of information is of great important for tomato growers as it can help them to make intelligent cultivar decision (Murray et al 1999).

For better result during crossing, it is imperative to consider the observation of Jolli (2004) that retention of five fruits per plant in tomato recorded significantly higher seed weight per fruit (0.966 g), number of seeds per fruit (114.74) over all fruits retained per plant (0.653 g, 68.91, respectively). But Basavaraj (2006) recorded significantly maximum crossed fruits per plant (5.55), maximum fruit set percentage (34.32), number of seeds per fruit(52.69), seed weight per fruit(2.90 g), hundred seed weight(6.23 g), seed yield per plant (17.65 g), and seed yield per ha (980.27 kg) when four female flowers crossed with one male flower compared to ten female flowers crossed with one male flower(3.93, 25.3%, 47.74, 2.44 g, 5.89 g, 10.56 g and 586.51 kg), respectively in bhendi seed production.

However for F_1 seed growers, higher seed yield per plant (8.16 g) was recorded in 15 fruits per plant compared to five fruits per plant (5.46 g). This is advancement over the earlier report of Revanappa (1993) who noticed significantly higher number of seeds (95.49) per fruit in chilli with NAA 20 ppm spray at 40 and 60 DAT, compared to water spray (79.30). Although, while the former emphasizes on effective carrying-capacity of the plant per stand, the latter raised the uses of hormones to induce seed yield; thus if both are combined where feasible, fantastic result could be inevitable. It is also here necessary to include that as in most self-pollinating plants, the viability of tomato pollen is limited, the isolation distance required in foundation seed plot is 6.5m between one farm and the other for different varieties which in practical terms is the effective distance tomato pollen can travel under field conditions and remain viable (Rick. 1976), and 10-15m for the breeder seeds.

4. Conclusion

I submit that the real value of the lines designated for developing hybrids is not based on their own performance *per se* but the performance of their F_1 hybrids; hence evaluation of parental lines for combing ability is recommended. Workers are advised to explore potentials

of the landraces at boosting heterotic expression in expected new variety among other benefits.

References

[1] Basavaraj, 2006, Studies on hybrid seed production of bhendi (Abelmoschusesculentus (L). Moench).M.Sc (Agri.) Thesis, Uni. Agri. Sci. Dharwad (India).
[2] Connecticut Agricultural Experiment Station: Prunning, Training, and Supporting Tomatoes; Francis J. Ferrandino (2010)
[3] Cooper, M. and D.W. Podlich. 1999. Genotype x environment interactions, selection response and heterosis. In: J.G Coors and ShivajiPandey [eds.], The Proceedings of an International Symposium "The Genetics and Exploitation of Heterosis in Crops", CIMMYT, Mexico City, Mexico, 17-22 August, 1997. Madison, USA, American Society of Agronomy, pp. 81-92.
[4] Daskaloff, Ch. 1942. ErgebnisseausKreuzungen: Sol. Racemigerum x Sarya und Plowdiwer
[5] Züchter SIV/5:105-111.
[6] Dielen V, Quinet M, Chao J, Batoko H, Havelange A, Kinet JM (2004) *UNIFLORA*, a pivotal gene that regulates floral transition and meristem identity in tomato (*Lycopersiconesculentum*). New Phytol 161 393–400.
[7] Falconer, D.S.(1989). Introduction to quantitative genetics (2nd ed). John Wiley & Sons, New York.
[8] Francis, J. Ferrandino (2010): Connecticut Agricultural Experiment Station: Prunning, Training, and Supporting Tomatoes.
[9] Gladis, T; Hammer K, ;Dathe, H. H. and Dellmann, H (1996) Morphogenetic studies of tomato. Plant Genetic Resources
[10] Jolli, R. B., 2004, Standerdization of hybrid seed production techniques in tomato (Lycopersiconesculentum Mill). Ph. D. Thesis, Uni. Agric. Sci., Dharwad (India).
[11] Melchinger, A.E. 1993. Use of RFLP markers for analysis of genetic relationship among breeding materials and prediction of hybrid performance. In: D.R. Buxton, R. Shibles,
[12] R.A. Forsberg, B.L. Blad, K.H Asay, G.M. Paulsen, and R.F. Wilson. [eds.], International Crop Science I. International Crop Science Congress, Ames, Iowa, USA, 14-22 July, 1992, Madison, WI, USA, Crop Science Society of America, pp. 621-628.
[13] Pnueli L, Carmel-Goren L, Hareven D, Gutfinger T, Alvarez J, Ganal M, Zamir D, Lifschitz E (1998) The *SELF-PRUNING* gene of tomato regulates vegetative to reproductive switching of sympodial meristems and is the ortholog of *CEN* and *TFL1*. Development 125 1979–1989.
[14] Revanappa, 1993, Response of green chilli (Capsicum annuum L.) genotype to nitrogen levels, plant density and growth regulators. Ph. D. Thesis, Uni. Agric. Sci.
[15] Rick, C.M. 1950. Pollination relations of *Lycopersiconesculentum* in native and foreign regions. Evolution 4:110-122.
[16] Russell, G. P.vanGardingen, and G.W.Wilson.1993.Using physiological information about varieties: the way forward? Aspects of Appl. Biol. 34:47-56.
[17] Sawhney, U. K and Dabbs, D .H. (1978): Gibbrellic acids induced multilocular fruit in tomato. Canadian J. of Bot 81:3857-3863.
[18] Sperling L. and Cooper D (2003). In Understanding seed system and strengthening seed security. Internal document .FAO Rome.
[19] Temperini, O., G. Colla, R. Campinelli, C. Piccioni, and R. Martellucci. 2001. Agronomic and commercial evaluation of some processing tomato hybrids. InformatoreAgrario. 57:75-79.
[20] Yordanov, M. 1983. Heterosis in tomato. In: R. Frankel [ed.], Heterosis: Reappraisal of Theory and Practice. Springer-Verlag, pp. 189-219.
[21] Zhutchenko, A.A. 1973. Tomato Genetics.
[22] Shtintza, Kichinev, Moldova. Hallauer, A.R 1999.Heterosis. What have we learned? What have we done? Where are we headed? In: J.G Coors and ShivajiPandey [eds.], The Proceedings of an International. Symposium "The Genetics and Exploitation of Heterosis in Crops", CIMMYT, Mexico City, Mexico, 17-22 August, 1997, Madison, USA, American Society of Agronomy, pp. 483-492.

Author's Profile

Aromolarann Benserah obtained his MSc. in Genetics and Planting from Abubakar Tafawa Balewa University (formerly Federal University of Technology) Bauchi, Nigeria. He was the Secretary (Technical), Strategic Study Group on Adoption of Agricultural Biotechnology set up by the Federal Ministry of Agriculture. He is the substantive Deputy-Director, Seed Research in the National Agricultural Seeds Councils, Nigeria. When Benserah is not playing the role of innovator; he remains ready-adopter of every proofing technology with keen interest in sustainable agriculture and environmental protection. Obviously, in those countries that have already acquired advanced technologies, this might mean nothing new to them; but for most third world countries in West, East Africa and the Caribbean where tomato breeding suffers paucity of attention, this is expected to ignite a deserving attention not only on tomato, but to all others in the Solanacea family.