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Review

Increasing production of soybean using biotechnology approach in Nigeria

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Soybean production in Nigeria has increased tremendously through the performance of improved varieties. This is as a result of increased demand for the crop. Production cannot however meet the demand due to various challenges faced by the crop. This range from biotic factors like rust to abiotic factor like pod shattering. Using biotechnological approach has provided some solutions to trait improvement in diseases, pest, grain yield and nutrient enhancement of the crop. Biotechnological tools have helped in solving some production constrains like weed (development of Round-up ready soybean varieties) which has enhanced and increased soybean production worldwide. New varieties have also been incorporated with improved nutrient content and disease tolerance. Despite these efforts however, biotechnology faces some challenges due to cost, consumer test and environment acceptability.

Key words: Soybean, productivity, biotechnology, Nigeria.

INTRODUCTION

Soybean [*Glycine max* (L.) Merr.] is a legume crop with high protein content (40%) and high-quality oil (20%) (Osho, 2003). Soybeans are the primary source of the world's supply of protein and vegetable oil. The demand for increased production of soybeans is forecasted to mirror the world's population growth and demand for protein and edible oil. Soybeans are grown in many parts of the world and are a primary source of vegetable oil and protein for use in food, feed, and industrial applications (Endres, 1992, 2001). Soybean was domesticated in the eleventh century BC around northeast China (Hymowitz and Shurtleff, 2005). It may have been introduced to Africa in the nineteenth century by Chinese traders along the east coast of Africa (Giller and Dashiell, 2006).

Reports indicate that soybean was cultivated in Tanzania in 1907 and Malawi in 1909 (Giller and Dashiell, 2006). African countries with the largest area of production are Nigeria (650,000 ha), South Africa (245,000 ha), Uganda (147,000 ha), Malawi (79,480 ha), and Zimbabwe (69,900 ha).

Nigeria is the largest producer of soybeans in Africa. Soybeans were first introduced into Nigeria in 1908 (Fennel, 1966), but the first successful cultivation was in 1937 with the Malayan variety (undated), which was found suitable for commercial production in Benue State (Oyekan, 1985). The producing areas of Central Nigeria have been responsible for a large proportion of the domestic requirement of this cheap source of plant protein. Today, soybean has made a successful incursion into the diet of many Nigerians, particularly children and nursing mothers. Soybean derivatives such as soy-gari, soymilk, soy-ogi and soy-lafun have been developed and found to be good substitutes for food ingredients like

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melon, cow milk and cowpea (Osho, 2003).

Nutritionally, soybean has twice the protein of meat or poultry and contains all eight essential amino acids needed for childhood development. In Nigerian markets, soybeans cost about one-fifth as much as other forms of protein, including dairy and fish, and are easier to store and transport. They also fix atmospheric nitrogen, which reduces the need for farmers to purchase fertilizer.

Development of improved soybean varieties and utilization technologies

The Malayan variety introduced to Nigeria was low yielding, susceptible to bacterial diseases and late maturing (Smith et al*.,* 1995). The latter characteristic exposes soybean to pod shattering due to the desiccating action of the seasonal Harmattan wind. Moreover, most soybean varieties could not nodulate in association with the native rhizobia indigenous to African soils and the seed quickly lost viability, which made it difficult for farmers to store it until the next cropping season (Dashiell et al., 1987). Over the last two decades, the International Institute of Tropical Agriculture (IITA) has made substantial efforts to improve the productivity of the crop by developing high yielding, early maturing varieties capable of nodulating in association with local rhizobia, and possessing other good agronomic traits (IITA, 1994). Improved soybean varieties released in Nigeria today, include TGx 849-313D, TGx 1019-2EN, TGx 1019-2EB, TGx 1447-2E, TGx 536- 02D, TGx 306-036C, TGx 1485-1ED, and TGx 1440-1E (IITA 1994); TGx1835-10E, TGx1904-6F, TGx 1987-62F and TGx1987-10F (Table 1).

Following the development and introduction of improved varieties, many food recipes using soybean were found to be highly acceptable to Nigerians, including their incorporation into traditional local dishes (Osho and Dashiell, 1998). The rapid growth in the poultry sector and oil mill processors like SALMA Oil Mills in Kano, Grand Cereals in Jos, ECWA Feeds in Jos, AFCOT Oil Seed Processors, Ngurore, Adamawa State, and PS Mandrides in Kano and a host of others in different parts of the country has increased demand for soybean in Nigeria. Soybean production is now increasing as more farmers are becoming aware of the potential of the crop as cash/food crop especially in the guinea savannah zone of Nigeria (Table 2). It has also increase the income of small scale farmers as it is a cash crop for domestic and export markets. The market for soybean in Nigeria is growing very fast with opportunities for improving the income of farmers. In Kano State, a bag of soybean was sold for N15,000 while in Oyo state it was sold for N12,000 last year. Presently, production cannot meet demand on ground. In order to meet this demand, production acreages are increasing in key global areas. However, technologies to increase production efficiency through transgenic trait control of yield-robbing biotic and abiotic constrains have become a reality.

Table 1. Improved soybean varieties and the year they were released in Nigeria.

Variety	Year released
TGx 536-02D	1980
TGx 1019-2EB	1980
TGx 1485-1D	1986
TGx 1830-20E	1986
TGx 1740-2F	1991
TGx 1871-12E	1991
TGx 1876-4E	1991
TGx 1895-4F	1991
TGx 1895-33F	1991
TGx 1895-49F	1991
TGx 1904-6F	1996
TGx 1904-7F	1996
TGx 1910-16F	1996
TGx 1835-10E	2008
TGx 1904-6F	2009
TGx 1987-62F	2010
TGx1987-10F	2010

The main challenges for soybean production in Nigeria that needed research attention today are low yield, low seed viability, poor natural nodulation, high shattering, and lack of appropriate processing and utilization methods. The low productivity of soybean could be attributed to lack of high yielding improved varieties (>3-4t/ha), biotic and abiotic stresses and absence of crop management technologies.

New improved varieties

In addition to improvement in agronomic traits to enhance production and consistency of production, soybean rust caused by the fungus *Phakopsora pachyrhizi* is increasingly becoming one of the most important constraints to soybean production. It has become a threat to soybean production in west, central, east and southern Africa. This foliar disease can cause 40-80% yield loss under African conditions (Tefera et al., 2009). IITA in collaboration with National Cereals Research Institute (NCRI) has developed resistant varieties for this disease (Table 3). These varieties are high yielding, early maturing and suitable for cultivation in the rust endemic areas of Nigeria. There is need to rapidly develop improved varieties that are resistant or tolerant to biotic and abiotic stress such as rust, cercospora leaf spot soybean mosaic virus which are becoming production constrain in the new areas of soybean production in Nigeria.

Table 2. Soybean production figures for some States in Nigeria (2007-2011).

Year	Production in metric tones					
	Nasarawa	**Katsina**	**Kano**	**Oyo**	**Benue**	**Kaduna**
2007	2390	1980	2609	2700	1748	1125
2008	2710	3052	4723	2700	1798	1069
2009	4370	3518	6552	2800	1817	1126
2010	6350	3514	6582	2900	-	1078
2011	2390	-	1259	2800	-	-
			Area in Hectares			
2007	3400	2041	1870		8783	7533
2008	2120	2563	2559		9033	7373
2009	3730	2550	6094		9084	7529
2010	5800	2647	9890		-	6878

Table 3. Grain yield (kg/ha) performance of TGx 1987-62F and TGx 1987-10F in multilocation trials for three years in comparison with check varieties in Nigeria.

Variety	2008	2009	2010	Mean	% increase over TGx 1835-10E	% increase over TGx 1485-1D
TGx 1987-62F	2241	1334	1946	1841	41	50
TGx 1987-10F	2161	1225	1770	1719	32	40
TGx 1835-10E		1005	1599	1302		
TGx 1485-1D	1699	574	1412	1228		
Trial mean	1891	1126.4	1892.5	1637		
SE	92	142.2	128.5			
P (Variety)	0.0001	0.0000	0.0001			

Soybean breeding vs Biotechnology

Today, the modern soybean breeder has additional tools provided by biotechnology to develop improved soybean varieties. Although modern biotechnology will never replace conventional breeding research, but rather will enhance and improve upon the efficiency of plant breeding. Biotechnology tool can genetically engineer soybean plants with unique genes, but plant breeding is necessary to put the new trans-genes via sexual reproduction into the proper genetic background so that it is adapted to the intended areas of use. For example, genetically engineered plants from the laboratory are often poor seed yielders, do not have insect or disease resistance, do not have the proper maturity, and so forth to compete with existing varieties in the market. This is because such varieties have not been exposed to the hazard of environment. Seed yield is of paramount importance, because growers cannot profitably grow new varieties aided by biotechnology if they are not competitive in yield to the best varieties already in the market.

According to Frey (1996), there are a number of factors that plant breeders need to consider before using biotechnology to develop new improved varieties. These include: "(a) the need for and utility of genes accessible only from incompatible species; (b) the relative costs of biotechnology and traditional breeding methods for cultivar development; (c) the relative ease whereby plant traits can be manipulated with biotechnology versus traditional breeding methods; (d) the distribution of the benefits of biotechnical inventions; and (e) the acceptance of genetically modified crop cultivars by farmers, society, and regulatory agencies. Cost is a considerable factor in determining whether to embark on soybean development using biotechnology. The controversy usually surrounds the consumption of GM cultivars and not biotechnology per se (Frey, 1996). Individuals do not generally object to the tools provided by plant biotechnology, such as tissue culture, marker-assisted selection (MAS), quantitative trait loci (QTLs), chromosomally engineered plants, genomics, and so forth. It remains to be seen if the world's people will openly embrace biotechnologically derived crop plants, including soybean, in the future.

Molecular breeding approaches for enhanced soybean production

One of the challenges facing modern soybean breeders is the fact that the germplasm base is extremely narrow (Carter et al., 1993; Sneller, 1994). Gizlice et al. (1994) found that only six ancestors constituted more than half of the genetic base of North American soybean germplasm. This poses a potential threat to soybean improvement and perhaps biotechnology might help alleviate this potential threat. Soybean breeding programs with access to molecular breeding technology have greatly enlarged tool kit for an enhanced probability of success in cultivar development.

Transformation of soybean is becoming more efficient, but still more efficiency is desired (Somers et al., 2003). One of the best examples of biotechnology intervention in soybean research is the development of soybeans that are tolerant to the herbicide glyphosate. Unlike previous traits in soybean, the rapid commercial adoption of glyphosate-tolerant soybeans provided tangible benefits to the grower, and enhanced productivity that fueled the trait adoption (James, 2001; Carpenter et al., 2002). Since their introduction in 1996, glyphosate-tolerant soybeans have grown to occupy over 33.3 million hectares—more than 46% of the global soybean acreage. Biotechnology-derived insect resistance traits in cotton and corn have created the benchmark for the use of biotechnology for controlling key pests in soybean. Among the benefits that growers expect are lowered insecticide uses, better control of key insect pests with less scouting and reduced risks of losses due to suboptimal timing of an insecticidal application, convenience to the grower, safety to the applicator, and more consistency in year-to-year performance in a farm pest management program. The development of virus-resistant soybeans using biotechnological methods has been initiated and evaluated by several groups (USDA APHIS, 2003).

Improving soybean agronomic trait

Despite the wide-ranging impact of biotechnology solutions, there are additional biotechnology tools that are quietly, yet effectively, improving the productivity of soybeans. One of these is the use of molecular markers, which help scientists track and select key genes during breeding. Pod shattering in soybean has constituted a great challenge to soybean improvement in Nigeria especially in the guinea savannah ecology where sunshine is high at maturity period of the crop or during the hamattan wind. Losses up to 80% have been recorded as a result of pod shattering (Tefera et al., 2009). Results have indicated that early maturing soybean varieties can hold seeds relatively well for the first three weeks after maturity (WAM). However, differences were noted starting from the fourth WAM. Non-irrigated soybean shattered faster than irrigated soybean after three weeks. Irrigated soybean held seeds longer than non-irrigated soybean during the fourth week; however, seed shattering became greater after four weeks even in the irrigated study. Seed dispersal mechanisms are crucial in maximising yields of soybean crop plants and remain a reoccurring issue for which unsynchronised pod shattering leads to significant yield losses. The fruit soybean is a silique which consists of two valves that protect the seeds and fused to a central replum by a specific tissue called valve margin. Valve margins differentiate into narrow stripes of cells consisting of a lignification layer (LL) and a separation layer (SL). Manipulation of gibberellin levels in soybean pod has given a novel approach to modify and regulate valve margin development and thereby control pod shattering. Valve margin defects clearly demonstrated that local production of Gibberellin Acid (GA) in valve margins is critical for the differentiation of this specialized tissue. Therefore, reducing the GA level by modifying the level of GA leads to a reduction in pod shattering without fully eliminating seed release.

Improving soybean resistance to pest and diseases

Traditionally, plant breeding strategies have been successfully used to develop a large number of disease resistant varieties. However, the increasing intensity of crop management has been accompanied by a growing number of diseases and a large number of pathogenic strains that have out-placed the development of new resistant plant varieties using conventional plant breeding strategies. This result in unwanted effect such as reduction in yield and fertility are observed in the transfer of the dominant resistant gene. Transfer of resistance gene into high yielding crops is a time consuming process. The incorporation of specific disease resistance trait in plant through genetic engineering offers a means to prevent disease associated losses without damaging the environment. Non-conventional strategies (biotechnology) for the production of disease resistant crop plant have exploited gene transfer technology for molecular resistance breeding (Carpenter et al., 2002). Such strategy include 1) expression of gene of plant defense response pathway component, 2) expression of gene encoding plant, fungal or bacterial hydrolysis, 3) expression of gene elicitors of defense response.

Another emerging tool of biotechnology is genomics, which refers to the study of the function and structure of genes. The soybean genome, as with genomes of other species, holds a vast resource of blueprints that determine what this great plant can provide. Genomics is helping researchers understand soybean DNA structure and function to change traits that affect pest resistance, yield, and grain composition. This understanding is converted to knowledge-based tools to develop gene markers for trait selection or trait solutions by use of specifically enhanced genes and promoters. As an example, public researchers at Indiana University have been able to use genomics tools, in combination with traditional trait mapping, to identify disease resistance genes for response to soybean bacterial blight (Carpenter et al., 2002). Genomics, in combination with other approaches, is helping researchers address the need for protein to meet the needs of our global community. Protein genes appear to be a potential source for fungal resistance. The PR proteins in particular play a direct role in defense by attacking and degrading pathogen cell wall components. Typical candidate genes are that encoding chitinases and ß-1,3 glucanases. Increasing expression of individual and multiple PR-proteins in various crops have demonstrated some success in enhancing disease resistance in particular pathogens (*e.g.,* in rice against *Rhizoctonia solani*, the sheaths blight pathogen). A recent research shows a chitinase gene from an anti-fungal biocontrol fungus species (*Trichoderma viride*) confers transgenic resistance against the rice sheath blight pathogen. A rice PR-5 protein gene in wheat delays onset of symptoms caused by the wheat scab pathogen.

The soybean cyst nematode (SCN) is another destructive soybean pest, which causes a lot of yield losses every year. Nematodes attach to roots, causing significant damage, plant stunting and yellowing, and yield loss. While attached, female nematodes are fertilized by male nematodes and produce a large number of eggs. At season's end, the female dies and the eggs remain in her body, which forms a protective shell or *cyst*. Nematode cysts may remain in infested fields for more than a decade. Field screening has been the traditional approach to battling SCN. This method has several challenges: It is labor intensive, destructive, and costly. Cysts are the size of pinheads and are difficult to see with the naked eye. The genetics of SCN resistance are complex, requiring that large numbers of plants be inspected to identify varieties with resistance.

Gene mapping has been used to identify the location of SCN resistance genes on specific chromosomes. Marker-assisted selection is used to confirm the presence of these genes in experimental varieties. This assay requires only a leaf tissue sample to extract DNA. The DNA samples are placed on a nitrocellulose membrane and then DNA probes are added to the samples. If a DNA gene or genes of interest exist in the sample, the probes bind to it and allow for detection. This technology allows researchers to evaluate more experimental varieties, leading to higher yield income per acre on SCN-infested land and more SCN-resistant variety options.

Improving soybean nutrition

A less intuitive but equally important approach to improving soybean production would be to change the functional properties of soy proteins. These functional properties include solubility, water absorption, viscosity, gelation, emulsification, and flavor binding (Kinsella, 1979). Increasing the solubility of soy proteins at acidic pH ranges, for example, would allow whole, rather than hydrolyzed, proteins to be added to fruit juices with a consequent reduction in the bitter flavors associated with small peptides (Adler-Nissen, 1978). Improving the gelation properties of soy proteins could result in reduced processing and consequently reduce any possible off-flavors developed during the extended processing required for some soy ingredients (Kitamura, 1995).

Although there may be hundreds of volatile compounds associated with bad flavors in soy preparations (Stephan and Steinhart, 1999), many of these compounds are associated with the oxidation of the polyunsaturated fatty linoleic and linolenic acids (Frankel, 1987). These are the predominant fatty acids in soybean oil; their oxidation during bean storage and processing results in the formation of secondary products of lipid oxidation that impart off-flavors to soy protein products. Several years ago, a high-oleic soybean variety was developed in which the polyunsaturated fatty acids were reduced from 70% of the total fatty acids to less than 5% (Kinney, 1996; Kinney and Knowlton, 1998). This was accomplished with a transgenic silencing of a key gene associated with polyunsaturated fatty acid content—the Fatty Acid Desaturase 2 (FAD2) gene.

Conclusion

To help meet the challenges of increased soybean demand, biotechnology tools are being used to develop soybeans with improved nutritional value and greater resistance to disease, pest, herbicides, and drought. Soybean producers are increasingly turning to biotechnology for soybeans improvement because of the cost and time savings and reasonable yield enhancement these soybeans offer. Future traits offer the promise of further crop protection benefits, higher yield, and grain value enhancement through oil and protein modification. However, despite all these opportunities, biotechnology faces numerous challenges. Because of the cost of technology and regulatory clearance, it is challenging for developers to capture an acceptable return on biotechnology investments. In order for the full benefits of biotechnology to be realized by the world's farmers and consumers, there has to be global acceptance of biotechnology for crops improvement.

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