HYBRID RICE TECHNOLOGY IN EGYPT

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Abstract

One of the many options available, hybrid rice is a proven technology to increase rice productivity by 15 to 20%. The success story of commercial hybrid rice cultivation in China ,India,Vietnam, Philippines, and Bangladesh has encouraged Egypt to adopt such technology.

The hybrid rice research program in Egypt was started in 1995 supported by collaborative projects involving USA,FAO, and IRRI. By 2004, almost all components of the hybrid rice technology program were completed by producing the certified hybrid rice seed , which was made available for commercial cultivation of hybrid rice in farmer's fields during 2005.

The six main components of the hybrid rice program :(1) breeding, (2) seed production , (3) agronomic practices cultivation , (4) training , (5) extension , and (6) hybrid rice economics are discussed in details.

The program resulted in the development of two promising hybrid rice combinations ; SK 2034 H(HR1) and SK2046 H(HR2) , which out yielded the current commercial cultivars by 15-30 % , meanwhile possessed a similar performance to that of the most popular cultivar (Giza 178) regarding tolerance to biotic and abiotic stresses , and grain quality expressed as grain appearance , milling recovery , nutrient value and panel taste test .

Year 2005 is the start year for hybrid rice cultivation in Egypt on a commercial basis .

INTRODUCTION

Rice is considered the second main food cereal crop, after wheat, for Egyptian population. Also, it is the second exporting agricultural crop after cotton . The area cultivated annually to rice in Egypt is about 0.6 million ha, all is under irrigation ecosystem.

During the last fifteen years, Egypt's Rice Research Program has succeeded to raise the national average yield of rice by about 66%, from 5.70 t/h for the period1984-1986 to 9.45 t/h in the year 2002 (RRTC,2002). This achievement allowed Egypt to rank first for highest yield average among rice producing countries allover the world in the last five years. Several factors contributed to realize this achievement, most important of which was the development of some superior inbred varieties, covered almost 100% of the total rice area in Egypt.

In spite of the great progress achieved in rice productivity in Egypt, still there is a need to make another breakthrough to increase rice yields per unit area because

of high rate of population increase and consequently consumption continues to increase. An anticipated increase of 15 % and more in the national yield average through traditional inbred varieties, technology would require several years since current commercial varieties have expressed almost maximum yield potentiality. The alternative approach available would be through hybrid rice technology, which has proven to increase yield levels by 15 -30 % under normal and saline soils. The success story of commercial hybrid in China, India, Vietnam, Philippines and Bangladesh has encouraged Egypt to adopt such technology (Table 1).

Table 1. National yield average (t/ha) of inbred and hybrid rice varieties in rice producing countries.

Country	Hybrid variety	Inbred variety	Yield advantage %	source
China	6.67	5.09	30.9	Yuan,1998
India	6.33	5.22	21.3	Virmani,2002
Vietnam	6.30	4.84	30.2	Virmani,2002
Philippines	7.80	6.50	20.0	Virmani,2002
Bangladesh	7.48	5.79	29.2	Virmani,2002
Egypt	12.18*	9.45	28.9**	

* Average of multilocation yield trials.

**Projected yield advantage.

Preliminary hybrid rice research was initiated in Egypt in 1982, to determine natural fertility restoration of Egyptian varieties on some Chinese CMS lines, evaluate certain CMS lines, test productivity of some hybrid varieties and to estimate yield and determination of seed setting percentage of some CMS lines under Egyptian conditions. The hybrid program then was retained to give more chance for improving rice productivity through the development of new improved inbred varieties (Maximos and Aidy, 1994).

The hybrid rice research program was restarted in 1995 (Bastawisi *et al.,* 1998). After two years, a tri-lateral project entitled " Enhancement of hybrid rice research and development" sponsored by the Government of Egypt, the International Rice Research Institute (IRRI) and the USDA-ARS University of California completed the work. The project generated valuable breeding materials and good hybrid combinations. The program gained further strength through Food and Agriculture Organization (FAO) sponsored project " Training in hybrid rice technology through technical cooperation between developing countries TCP/EGY/8923 & 2801 (T)" with a main component of human resources training outside and inside the country which accelerated the hybrid rice technology in Egypt.

By 2004,the six main components of the hybrid rice technology program: 1) breeding, 2) seed production, 3) cultivation, 4) training, 5) extension, and 6)

economics, were accomplished. Two hybrid rice combinations viz. SK 2034 H and SK 2046 H were found to consistently outperform the best leading inbred varieties; Sakha 101 and Giza 178 by 20-30% under normal and saline soils . These two hybrid combinations were evaluated in verification yield trials and on-farm demonstration plots during 2003 and 2004 seasons. SK 2034 H is characterized by relatively short grains and intermediate amylose content, while SK 2046 H is of medium fine indica grain type with intermediate amylose content. Salient features of these two hybrids are given in Table (2). In addition to these hybrids, second and third stage hybrid combinations are in the development pipeline. Yield average and range of some promising hybrids under normal and saline soils, and percentage of standard heterosis over the local inbred check variety (Giza 178), as well as their accessory characters are presented in Table (3).By releasing the first hybrid rice variety for commercial cultivation, the hybrid rice program in Egypt has been established. Components of the hybrid rice technology program and the future prospectives of hybrid rice in Egypt are discussed in details.

1. Components of Hybrid Rice Program

1.1 Breeding :

In Egypt, the three-line breeding method for hybrid rice is used ; however, the two-line method Thermo-sensitive genic male sterility (TGMS) and Photoperiod-sensitive genic male sterility (PGMS) is used too, but it is in the initial stage (Bastawisi *et al.*, 2002 & 2003). Components and procedures of the hybrid rice breeding program are presented in Table (4). The breeding program involves:

- Identification and development of parental lines which is accomplished through a series of nurseries , namely , source nursery, testcross nursery, CMS maintenance and evaluation nursery, backcross nursery, combining ability nursery, restoring ability nursery, improvement of parental line nursery, TGMS and PGMS nurseries, and wide compatibility nursery. Diagram and time sequence of hybrid rice breeding in Egypt is shown in fig.1.
- Evaluation of experimental hybrids through yield trials such as multilocation, advanced, preliminary, observational, and on farm yield trials. Five hybrid rice combinations were identified in both normal and saline soils, Table(3).

1.2 Seed production :

The tasks of the seed production components are to: 1) maintain promising CMS lines (A/B), 2) produce seed for experimental yield trials (A/R), and 3) obtain nucleus and breeder seed of parental lines for commercial production of hybrid seeds.

For maintaining purity and high quality of hybrid seeds, many steps must be considered such as isolation conditions, flowering synchronization of parental lines, roguing, GA_3 application, flag leaf clipping and supplementary pollination.

Hybrid rice seed production is a tedious work and requires high level of accuracy and to obtain cost effective seed production. The environment in Egypt

appears to favor high out-crossing, seed setting and seed quality. The average seed yield under experimental plots is now 2.9 t/ha, ranging from 2.0 to 3.8 t/ha.

Based on seed production experiments under research and commercial levels, an optimum package of recommendations for seed production was developed (Table 6).

Table 2. Yield performance and salient features of two rice hybrids tested in on – farm and verification yield trails during 2000-2003 seasons

Hybrid	Parentage	Ecology	Yield (t/ha)		Standard heterosis %	Accessory characters		
			Range	Mean		HDG* (days)	Stature	Grain type
SK 2034 H	IR 69625A/ Giza 178 R	Normal soil Saline soil	10.1-15.3 5.1-6.6	11.27 5.65	22.6 31.7	103 106	Semi-dwarf	Short grain with intermediate amylose
SK 2046 H	IR 69625A/ Giza 181 R	Normal soil Saline soil	10.2-14.9 5.1-6.1	11.62 5.60	26.4 30.5	106 110	Semi-dwarf	Med. grain with intermediate amylose

*HDG: Days to heading

Table 3. Yield performance, standard heterosis and accessory characters of promising rice hybrids evaluated under normal and saline soils during 2000-2003 seasons .

Hybrid	Parents	Ecology	Yield (t/ha)		Standard Heterosis (%)	Accessory characters	
			Range	Mean		HDG*	Grain type
SK 2035 H	IR 70368 A/ Giza 178 R	Normal Saline	9.98-14.93 6.68-6.80	12.0 6.74	24.74 31.90	104 105	Med.
SK 2029 H	IR 68888 A/ Giza 178 R	Normal Saline	10.10-15.37 5.30-6.61	11.57 5.96	22.14 16.63	103 100	Med. Slender
SK 2010 H	G 46 A/ Giza 182 R	Normal Saline	10.63-12.95 -	11.34 -	25.16 -	102 -	Short Bold
SK 2058 H	IR 69625 A/ Giza 182 R	Normal Saline	11.12-12.51 5.76-6.34	11.82 6.05	22.87 18.40	100 98	Med. Slender
SK 2074 H	IR 69625 A/ Giza 5121 R	Normal Saline	- -	11.33** 7.29	12.96 42.66	99 102	Med

*HDG: Days to heading

**Tested for one year

Table 4. Components of hybrid rice breeding program.

	Component / Material	Remarks
I-	Identification and development of parental lines	
	* Source nursery (SN)	Hybridization
	* Testcross nursery (TCN)	Identification
	* CMS evaluation nursery (CMSN)	Maintenance
	* Backcross nursery (BCN)	Pedigree selection A & B line
	* Combining ability nursery (CAN)	Identification
	* Restoring ability nursery (RAN)	Selection R line
	* Improvement of parental lines	Improvement B & R line
	* TGMS nursery	Evaluation and pedigree selection
	* PGMS nursery	Evaluation and pedigree selection
	* Wide compatibility nursery (WCN)	Development
II-	Evaluation of experimental hybrids	
	* On-farm trials	Demonstration
	* Multilocation yield trial (MYT)	Replicated
	* Advanced yield trial (AYT)	Replicated
	* Preliminary yield trial (PYT)	Replicated
	* Observational yield trial (OYT)	Augmented design
	* IRHON	Augmented design
III-	Seed production of experimental hybrids	
	* CMS multiplication (A/B)	Seed increase
	* Hybrid seed production (A/R)	Increase for experiments
	* Purification A, B and R line	Purification

Table 5. List of stable CMS lines highly adapted to Egyptian environment

Entry	Cytosterility source*	Grain type**	Amylose content (%)
IR 58025 A	WA	L	15.8
IR 68888 A	WA	L	23.8
IR 69625 A	WA	M	22.9
IR 70368 A	WA	M	24.2
G 46 A	Gambiaca	MB	21.2

* WA = Wild abortive.

**L = Long, M = Medium, MB= Medium bold.

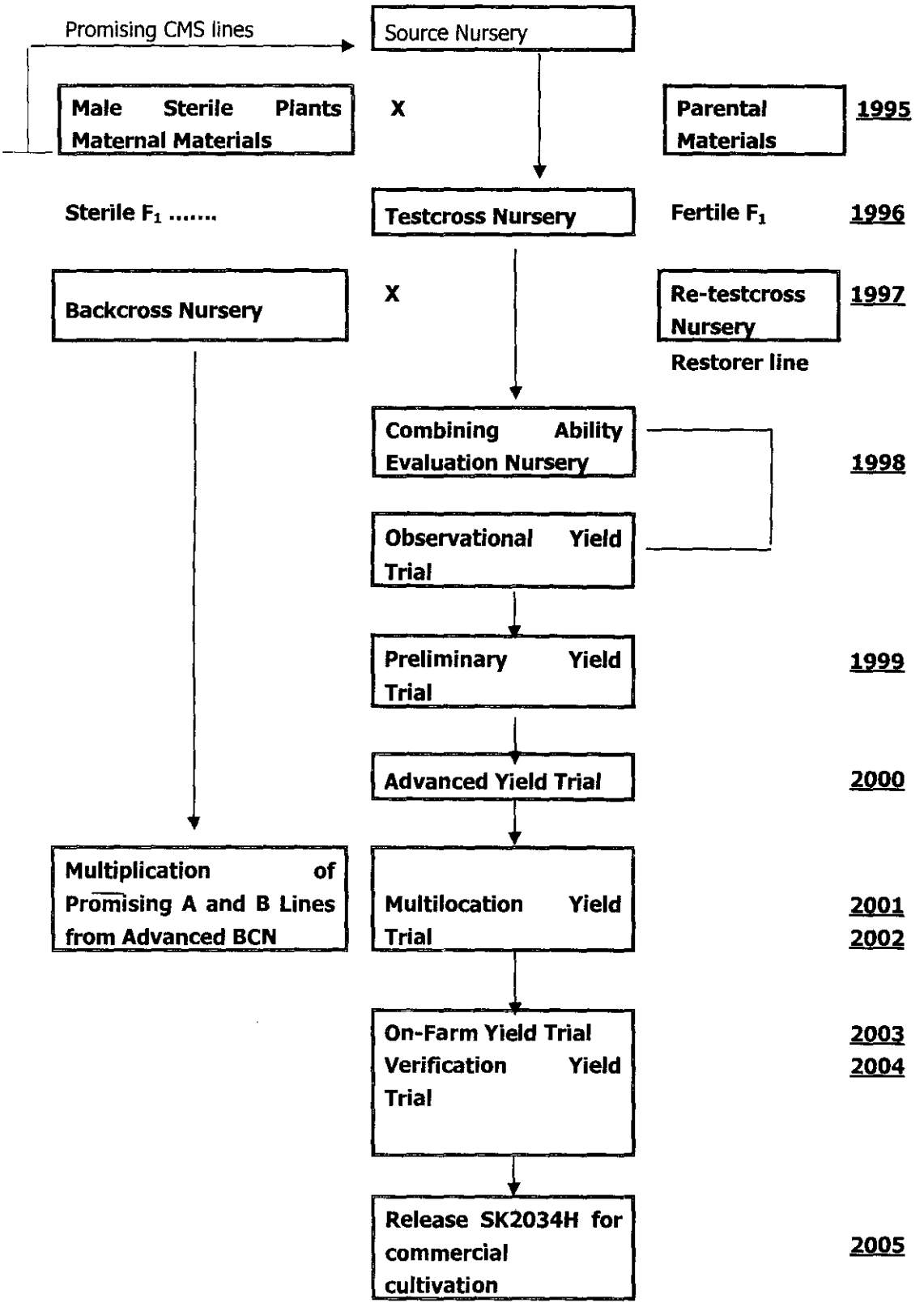

Fig. 1. Diagram and time sequence of hybrid rice breeding in Egypt

Table 6. Optimum package of recommendations for hybrid rice seed production and CMS multiplication

Operation	Particulars
Sowing date	April 25 - May 10
Seed rate	Seed parent : 27- 36 kg/ha Pollen parent: 9- 12 kg/ha
Nursery	Sparse seeding (42-57 g/m^2) to ensure seedlings with 3-5 tillers in 25 days
Row ratio	8 A line : 2 B line 8 A line : 2 R line or 10 A line : 2 R line
Number of seedlings/hill	1-3 for seed parent 2-3 for pollen parent
Spacing	Male : male 20 cm Male : female 25 cm and 30 cm Female : female 15 cm Plant : plant 15 cm
GA_3 application (BERLEX)	300 g/ha in 500 liters of water at 10% of heading in two split doses of 40% and 60% in consecutive days
Supplementary pollination	3-4 times a day at peak of anthesis time with 30 minutes interval
Roguing	- at vegetative phase based on morphological traits. - At flowering before anthesis. - At maturity based on grain characteristics and seed set rate after removing R line
Seed yield	- A x B : 2.5 – 3.0 t/ha - A x R : 2.0 – 3.8 t/ha

1.3 Cultivation :

Any promising hybrid combination cannot express its potential productivity unless an ideal package of recommended cultivation practices is made available. Necessary data were generated on optimum seed rate, seeding density in nursery, seedling age, number of seedlings per hill, planting date, plant geometry, fertilizer and irrigation requirements. An optimum package of recommendations is given in Table (7).

Table 7. Package of recommended practices for hybrid rice cultivation

Operation	Particulars
Seed rate	24-36 kg/ha
Nursery seeding density	57- 69 g/m^2
Spacing	20x20 cm
Seedlings/hill	1 – 3
Seedling age	25 - 30 days
Nitrogen application	150 kg/ha in three splits
Phosphorus	45 kg/ha
Potash	60 kg/ha
Zinc	30 kg/ha
Plant protection	Needed

1.4 Training:

The success of the hybrid rice technology would largely depend on the availability of trained manpower. The in-country training was organized at three levels: a) training of a core group, associated exclusively with hybrid rice breeding and seed production program at RRTC, Sakha, which is the main center for hybrid rice research in Egypt, b) short - term training course of two weeks on hybrid rice breeding and seed production technology given to 32 young scientists chosen at the national level , representing the fields of rice breeding , seed production , agronomy, and plant protection, Table(8), c) a one week training for 50 persons associated with commercial seed production involving seed growers, and seed production specialists from both public and private sectors, d) training of 100 extension officers on hybrid rice cultivation for three days, and e) a 2-day training course on hybrid rice cultivation for 202 farmers from hybrid rice targeted areas .

Table 8. In- country training conducted during the period 2001-2002

Nature of training	Target personnel	Number
Hybrid rice breeding	Breeders and seed production researchers	32
Hybrid rice seed production	Breeders and seed production researchers	32
Hybrid rice seed production	Seed production specialists and Seed producers	50
Hybrid rice cultivation	Extension personnel	100
Hybrid rice cultivation	Progressive farmers	202

1.5 Extension :

On-farm (15 sites/year) and verification yield trials(20 sites/year) were conducted on farmers fields from 2002-2004 .The package of recommendations for hybrid rice cultivation was applied, the results confirmed the superiority of the hybrids over inbred varieties by 15 – 30 %. The average performance of On-farm yield trails during 2002 to 2004 seasons are presented in Table (9).

Table 9. Average yield performance of the two promising hybrids compared to Giza 178 cultivar under On- farm yield trials during 2002 to 2004 seasons.

Variety	Yield average t/ha	Range t/ha	Standard Heterosis %	Standared Heterosis Range
SK2034 H(HR1)	13.26	11.42 – 16.09	17.24	19.96 – 23.58
SK2046 H(HR2)	13.59	11.80 – 15.71	19.26	20.66 – 23.95
Giza 178	10.97	9.52 – 13.02	-	-

1.6 Economics :

Utilizing the experimental data of On–farm and verification yield trials, a cost benefit analysis was conducted for both hybrid rice seed production and hybrid rice cultivation (Sabaa, 2002).

1.6.1. Cost-benefit analysis of hybrid rice seed production (F_1) :

Table (10) presents the yield averages of hybrid rice seeds; (F_1) to be 2.5 t/ha + 2.3 t/ha from the restorer line (R), with a net return of about 5880 LE/ha while the annual return to investment has reached 172% (86.0% in six months). Assuming a marketing margin of about 33%, farmers can get the hybrid rice seeds at a price of 10 LE/kg (1.6$ / Kg), about 4-5 times the cost of inbred varieties' seed.

Table 10. Cost-Benefit analysis of hybrid rice seed production

Item	Hybrid seed production	Remarks
I. Costs (LE/ha)*:		
Labor	1193	50% more
Machine	759	
Seeds	720	48 kg x LE 15
Fertilizer	492	Nitrogen, phosphorus, potassium and zinc sulphate
Plant protection	145	
Other costs	350	Post harvest and
Farm anagement and technical advice		miscellaneous
Land rent	1660	
Total costs	1500	
	6819	
II. Benefits :		
Yield of (F_1) seed (t/ha)	2.5	
Yield of (R) rice (t/ha)	2.3	
F_1 farmgate price (LE/ton)	4500	
R farmgate price (LE/ton)	630	
Total value of output	*12699*	
III. Net return (LE/ha)	5880	
IV. Return to investment % **	86	

*One $ = 6 LE

** Six months

1.6.2. Cost-benefit analysis of hybrid rice cultivation :

Table (11) presents cost benefit analysis of hybrid rice varieties compared to conventional varieties (inbreds). The average yield of hybrid rice varieties (based on yield average of multilocation,on farm and verification yield trials) was 12.18 t/ha compared to 10.21 t/ha of the conventional varieties, with yield advantage of 19%. The net benefit was 44% compared to inbred variety, and the return to investment reached 179% (89.5% in six months) compared to 128% for the conventional varieties. The only difference between hybrid and inbred cultivars was the cost of seed (66.5% higher in hybrids).

Table 11. Cost-Benefit analysis of hybrid rice cultivation

Item	Hybrid varieties	Conventional varieties
I. Costs (LE/ha)*:		
Variable costs :		
- Seed	333	200
Fixed costs :		
- Labor	795	795
- Machine	759	759
- Fertilizer	290	290
- Plant protection	145	145
- Other costs	228	228
Sub total	*2550*	*2417*
- Land rent	1500	1500
c) Total Costs	*4050*	*3917*
II. Benefits :		
a) Yield (t/ha)	12.18	10.21
b) Farmgate price (LE/ton)	630.00	630.00
c) Total value of output	*7673.4*	*6432.3*
III. Net benefit (LE/ha)	3623.4	2515.3
IV. Return to investment % **	89.5	64.2

*One $ = 6 LE

** in Six months

2. Hybrid Rice Grain Quality.

Grain quality performance expressed as grain appearance, milling recovery, eating and nutrient quality , and panel taste test of the two promising hybrids, SK2034H and SK2046H was found to be similar to that of the most popular commercial cultivar, Giza 178(Tables12,13,14).

Data presented in Table (12) exhibits some physical and milling quality characters for four rice varieties of which two are the promising rice hybrids, SK 2034H and SK 2046H , and the other two are the commercial cultivars, Giza 178 and Giza 181. Grain shape is expressed as the ratio of grain length to grain width. Both SK 2034H and Giza 178 belong to short grains. While SK 2046H and Giza 181 relate to long grains. Grain weight of the tested cultivars was heavy except for the cultivar Giza 178 which possessed the least weight (1.9 g).

Milling recovery of long grain rices recorded high values than short grain rices .This may be due to the grain filling period. Contrarily , short grain rice varieties exhibited higher head rice values than did long grain ones.

Table 12. Physical and milling quality characters of two promising rice hybrids and two commercial cultivars.

variety	Grain shape	100-grain weight(gm)	Milling (%)	Head rice (%)
SK2034 (HR1)	2.2	2.4	66.2	56.8
SK2046 (HR2)	4.38	2.5	69.1	53.3
Giza 178	2.34	1.9	65.2	57.4
Giza 181	3.92	2.6	69.2	56.8

Cooking and eating quality characters; i.e. amaylose content, gel consistency, and grain elongation and chalkiness of grain are presented in Table (13) . The two promising rice hybrids SK2034H and SK2046H were of higher amylose content (22.5 % and 23.7 %, respectively) compared to the commercial inbred rice varieties (Giza 178 and Giza 181). All tested rice varieties were of soft gel consistency, ranging between 80-100 mm. These two characters are the main factors affecting gel viscosity of milled rice and softness after cooking.

The highest elongation % was recorded for Giza 181 followed by Giza 178 while the two rice hybrids exhibited the least but almost equal values .

The amount of chalkiness has a direct effect on the translucency of milled rice grain which affects milled rice marketing. Giza 181 recorded the lowest chalkiness (0.1%) while , SK2034 possessed the highest value (14.4%) among the tested rice varieties.

Table 13. Cooking and eating quality characters of two promising rice hybrids and two commercial varieties.

varieties	Amylose %	Gel Consistency mm	Elongation %	Chalkiness %
SK2034 (HR1)	22.5	100	31.5	14.4
SK2046 (HR2)	23.7	100	31.7	9.5
Giza 178	16.9	80	33.9	10.0
Giza 181	20	100	43.3	0.1

Palatability characters are the main indicator of the consumers demand for the different rice entries. It differs according to the consumer's nutrient habit. Data recorded in Table(14) revealed that the rice hybrid SK2046 and the variety Giza 178 have a better grain shape than SK2034 and Giza 181. It must be taken into consideration that Egyptian consumers in general prefer varieties possessing bold to medium grain, high-translucency, low breakage and sticky after cooking. Giza 181 followed by SK2034H were better in the other panel taste test traits i.e. hardness, stickiness, odor and taste. Total scores of different tested rice varieties were very close and over 70 % of maximum score. These results revealed that rice hybrids can be accepted easily by Egyptian consumers.

Table 14. Panel taste test of two promising rice hybrids compared to two commercial varieties.

varieties	Shape 10	Breakage 10	Grain appearance 10	Hardness 10	Stickiness 10	Odor 10	Taste 10	Total 70
SK2034(HR1)	7	5	8	8	9	8	10	55
SK2046(HR2)	9	7	7	8	8	6	7	52
Giza 178	9	7	8	7	8	9	9	57
Giza 181	7	7	10	9	9	10	10	62

3. Future prospects :

a) Develop new parental lines exhibiting better tolerance / resistance to biotic and abiotic stresses.

b) Introduce wide compatibility gene/s to both two-line and three-line methods to raise the yield potential.

c) Utilize biotechnology tools to enhance and increase efficiency of breeding activities and facilitate hybrid rice seed production.

d) Introduce basmati rice hybrids to commercial production.

e) Grain quality of the promising hybrid combinations are in the same level of the leading inbred variety Giza 178,however more improvement work is needed for both inbred and hybrid varieties in order to attain premium grain quality.

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تكنولوجيا الأرز الهجين في مصر

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تعتبر تكنولوجيا الأرز الهجين أحد الأطروحات الهامة لزيادة إنتاجية محصول الأرز بنسبة تتراوح ما بين ١٥-٢٠% . وقد كان لنجاح تجربة إدخال زراعة الأرز الهجين التجاري في كل من الصين- الهند- فيتنام- الفلبين- بنجلادش دورا كبيرا في تشجيع مصر للدخول في هذه التكنولوجيا .

ويعتبر عام ١٩٩٥ هو البداية الفعلية للبرنامج البحثي للأرز الهجين والذي تم تدعيمه من خلال المشاريع القومية والدولية بالتعاون مع الولايات المتحدة- منظمة الأغذية والزراعة- معهد الأرز الدولي بالفلبين وفي نهاية عام ٢٠٠٤ أمكن استكمال جميع المكونات الخاصة بتكنولوجيا زراعة الأرز الهجين منتهية بإنتاج التقاوي المعتمدة لتكون متاحة لدي المزارع في عام ٢٠٠٥وتشمل مكونات برنامج الأرز الهجين الستة الأتي :-

١- التربية. ٢- إنتاج التقاوي. ٣- المعاملات الزراعية.

٤- التدريب ٥- الإرشاد . ٦- اقتصاديات الزراعة وانتاج التقاوي .

وفي عام ٢٠٠٥تم توزيع هجينين مبشرين ومعهما حزمة التوصيات الفنية علي المزارعين للإنتاج التجاري . وبالإضافة إلى الإنتاجية العالية في المحصول (١٥- ٣٠ % زيادة عن أعلي الأصناف الذاتية التلقيح التجارية) فان هذه الهجن تعتبر مقاومة للأمراض ومتحملة للظروف البيئية المغايرة وذات صفات جودة حبوب عالية متضمنة مظهر الحبوب- تصافي الضرب- جودة الطهي والأكل- وجودة اختبار التذوق وفي مستوي الصنف جيزة ١٧٨ . وإذا اعتبرنا عام ٢٠٠٤ هو العام الدولي للأرز فانه يعتبر في نفس الوقت عام إنتاج تقاوي الأرز الهجين المعتمدة في مصر .