RESEARCH PAPER
Asian Journal of Bio Science, Volume **7** | Issue 2 | October, 2012 | 138-144
Received : 17.03.2012; **Revised :** 18.05.2012; **Accepted :** 25.06.2012

Development of drought tolerant index in cotton genotypes based on relative water content and yield

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Water stress adversely affects both yield and fibre quality of cotton (*Gossypium spp* L.). A study was conducted to determine the relative water content (RWC) and drought tolerant index (DTI) of cotton plants under water stress in cotton. The experiment was conducted by adopting Factorial Randomized Block Design with three replications. The treatments comprised of water stress imposed at vegetative, squaring and boll development stages of crop growth. In case of drought tolerant genotype, the leaves maintained higher RWC and photosynthetic activities under water stress than that of drought sensitive genotype. Prolonged water shortages virtually affect all the metabolic processes and often result in severe reductions in plant productivity.

Key words : Relative water content, Yield, Drought tolerant index

How to cite this paper : Ananthi, K. and Vijayaraghavan, H. (2012). Development of drought tolerant index in cotton genotypes based on relative water content and yield. *Asian J. Bio. Sci.*, **7** (2) : 138-144.

INTRODUCTION

Cotton (*Gossypium* spp.; Family : Malvaceae) a leading natural fibre source, is grown in arid and semiarid regions of the world. It is a very important cash crop for Indian farmers and contributes around 30 per cent to the gross domestic product of Indian agriculture. It is considered as the 'white gold' and 'king of fibre crops'. Water use efficiency is a key factor determining plant productivity under limited water supply. Through intensive breeding programmes, cultivars have been developed that are grown commercially as annuals. The relative water content (RWC) was studied in drought tolerant and drought sensitive genotypes of cotton (*G. hirsutum* L.) during induction of water stress and posterior recovery (Asish Kumar *et al.*, 2008). In case of drought tolerant genotype, the leaves maintained higher RWC and photosynthetic activities under water stress than that of drought sensitive genotype. Flower and Ludlow (1986) proposed that RWC is an alternative measure of plant water status which tells upon the metabolic process in the tissue and lethal leaf water status. Upreti *et al*. (1998) noted changes in RWC under stress and normal conditions, the reduction being significant under stress condition. Crop management for both optimum yield and fibre quality is a realistic and important approach to take for a profitable cotton production system. Water availability is arguably the most limiting factor to profitable cotton production in the South East. Pace *et al*. (1999) suggested cotton cultivars that can endure and recover from drought are needed to minimize fruit loss and reduce the amount of water required for crop production. Minimum numbers of flowers were found when moisture stress was imposed at flowering stage (Kaur and Singh, 1992). Jordan (1983) reported higher rate of square and boll shed in cotton due to water stress. Varma (1975) reported more than 32 per cent of flower shedding and 58 per cent of boll shedding in cotton. Kaur and Singh (1992) found that flower number and percentage of boll abscission were decreased by water stress at flowering stage of cotton. Seed cotton yield decreased as the allowable water deficit increased (Cudrak and Reddel, 1988). Lint yield is generally reduced because of reduced boll production, primarily because of fewer flowers and also due to increased boll abortions when the stress is extreme and when it occurs during reproductive growth (Pettigrew, 2004). Seed yield and yield components are severely affected by water deficit.

RESEARCH METHODOLOGY

The aim of this experiment was to investigate the responses caused by progressive water stress and the necessary time for have biochemical and physiological changes of *Gossipium* spp. during the vegetative, squaring and boll development stages. For present investigation, twenty one genotypes including eight parents, four F_1 hybrids, five F_2's and four back crosses along with parents were subjected for genetic diversity analysis using physiological features. Field trails were conducted in at *Kharif*, 2008 in the Department of Cotton, Centre for Plant Breeding and Genetics, TNAU, Coimbatore.

Treatments:

– T_1- Control
– T_2- Stress at vegetative
– T_3- Stress at squaring
– T_4- Stress at boll development

Varietal details:
Parents:

– JKC 770
– AS1
– AS2
– KC2
– KC3
– MCU 13
– Suvin
– Surabhi

F_1 hybrids:

– AS1XSuvin
– KC2XMCU13
– AS2XMCU13
– KC2X JKC 770

F_2's:

– KC2 x XMCU13
– AS3 x JKC 770
– AS2 x MCU13
– KC2 x JKC 770
– AS1 x Suvin

Back crosses:

– (AS2 x MCU13) x MCU13
– (AS2 x MCU13) x AS2
– (KC2 x MCU 13) x MCU 13
– (KC2 x MCU13) x KC2

Drought tolerant index (DTI):

An attempt was made to develop a drought tolerant index based on two physiological parameters such as chlorophyll stability index and relative water content. In a similar fashion yield data were also computed for arriving at a drought tolerance index. The following parameters were used (Zangi, 1998 and Jafary, 2002).

– The yield recorded in normal stress free environment (Yn)
– The yield recorded under drought (Yd)
– The yield recorded in all genotypes under normal environment (Yn*)

The drought tolerant index is defined by the above data for arriving at the following indices:

Drought tolerance index (DTI)=(Yd x Yn)/(Yn*)^2

RESEARCH FINDINGS AND ANALYSIS

Relative water content which is an important parameter for drought studies was recorded in F_1, F_2, and F_3 and back cross generations along with parents. In general it was observed that RWC was maintained at higher level in KC2 x MCU13 followed by KC2 x JKC770 and AS2 x JKC 770 in both F_1 and F_2 generations. This indicates that these three combinations were superior in terms of drought tolerance. The genotype (KC2 x MCU13) x KC2 maintained a higher relative water content in all stages than others even under the stress conditions (76.43, 78.84 and 77.38). Plant water stress was measured in terms of leaf water potential or leaf relative water content (Deivanai *et al*., 2010). Reduction in RWC results in loss of turgidity, which leads to stomatal closure and reduced photosynthetic rates (Sulian *et al*., 2007). The performance of genotypes for RWC (%), under water deficit condition, in which a sharp decline in RWC was recorded among the genotypes. Some previous studies (Jamauex *et al*., 1997; Altinkut *et al*., 2001; Colom and Vazzana, 2003) have shown that maintenance of a relatively high RWC during mild drought is an indicative of drought tolerance. Among the genotypes KC2, AS2 and MCU 13 recorded higher value of RWC percentage at all the stages of crop growth irrespective of the treatments (77.28, 79.06 and 79.37; 74.80, 77.02 and 77.78; 71.46, 75.07 and 75.63, respectively). However, the susceptible genotype Surabhi exhibited the lowest relative water content percentage of 61.45, 64.89 and 64.39 than other genotypes. RWC was maintained at higher level in KC 2 x MCU13 followed by KC2 x JKC770 and AS 2 x JKC 770 in both F_1 and F_2 generations. (Table 1 and Fig. 1).

Differences were noticed in seed cotton yield per plant due to the treatments. The stress imposed at squaring stage has shown a marked reduction in seed cotton yield when compared to the control. The seed cotton yield recorded as 128.99 in KC2 x MCU13 (F_2) irrespective of treatments. Significant differences were also observed between the genotypes, treatments and their interactions. The genotypes KC2 and AS2 had the highest value of seed cotton yield (120.28 and 110.22) than other genotypes at all stages irrespective of the treatmental effects. (Table 2 and Fig. 2) Among the backcrosses, (KC2 x MCU13) x MCU13 the tolerant genotype

Table 1 : Effect of drought on relative water content (RWC %) at different stages of cotton in F_1, F_2, back crosses along with parents

Stages Genotypes	Vegetative					Squaring					Boll development				
Parents	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean
V.CU 13	72.39	68.87	70.39	71.19	71.46	80.53	76.29	72.20	74.28	75.07	81.43	74.27	80.29	72.18	75.63
AS 2	76.46	74.23	69.3	79.2	74.8	82.27	78.29	80.52	78.11	77.02	80.15	80.54	78.39	79.65	77.78
JKC 770	67.18	64.39	64.33	67.29	65.8	71.34	65.25	67.52	64.27	66.37	64.71	67.1	71.4	63.2	66.44
KC 2	78.62	73.93	76.43	80.12	77.28	80.21	79.32	80.39	85.2	79.06	79.87	78.13	84.38	78.27	79.37
AS 1	68.29	55.64	62.39	73.28	64.90	76.23	76.29	78.44	78.76	70.47	78.45	65.39	72.10	72.54	70.94
Surabhi	66.26	56.49	66.73	65.32	61.45	70.23	72.21	66.23	68.12	64.89	63.38	56.46	67.43	65.28	64.39
KC 3	77.82	73.33	73.39	70.91	73.86	80.63	78.65	79.26	82.10	76.66	75.27	80.64	79.87	78.02	77.17
Suvin	69.46	65.21	65.47	71.21	68.09	82.1	79.43	78.9	82.87	73.75	71.02	79.76	64.42	76.32	73.50
F_1 hybrids															
AS1 x Suvin	75.48	66.48	74.44	73.22	72.41	76.39	72.33	68.24	70.22	72.13	70.88	74.22	76.77	70.88	72.43
KC 2 x V.CU 13	82.10	78.39	78.92	73.20	78.15	84.3	79.93	78.39	74.12	78.61	76.4	75.40	78.88	73.76	77.90
AS 2 x V.CU 13	83.15	79.39	72.10	68.32	75.74	80.21	78.53	77.28	76.10	76.76	74.10	72.22	75.44	75.66	76.07
KC 2 x JKC 770	81.22	80.62	77.39	78.33	79.39	76.38	83.2	78.30	80.22	79.45	72.32	70.33	83.22	71.10	77.96
F_2'S															
KC 2 x V.CU 13	80.34	80.12	78.22	82.43	80.28	82.12	80.54	79.56	79.20	80.31	78.30	78.28	70.45	69.30	78.53
AS 3 x JKC 770	83.33	81.42	80.15	84.54	82.36	83.21	82.54	84.42	85.30	83.03	79.25	84.76	72.40	67.48	81.01
AS 2 x V.CU 13	78.66	78.26	79.10	74.67	77.67	79.34	80.24	76.45	78.64	78.11	72.10	74.88	68.29	74.30	76.48
KC 2 x JKC 770	84.56	82.10	82.16	85.27	83.52	85.78	86.43	84.56	79.22	83.73	84.52	85.12	80.44	78.71	83.29
AS 1 x Suvin	73.44	73.21	74.42	68.29	72.34	77.80	74.9	74.24	77.29	73.99	65.39	68.24	76.34	62.84	72.34
Back crosses															
(AS2xV.CU13) x V.CU13	73.32	72.23	69.50	73.42	72.12	77.93	76.3	75.49	76.39	74.08	71.10	65.93	65.40	68.30	72.25
(KC2xV.CU13) x KC2	78.93	75.32	75.83	75.64	76.43	83.52	82.1	81.10	80.65	78.84	76.37	73.3	73.20	72.11	77.38
(AS2xV.CU13) x AS2	74.28	70.46	72.39	75.49	73.16	81.29	79.3	78.40	82.65	76.38	73.76	70.21	67.44	69.57	74.63
(KC2xV.CU13) x V.CU13	71.02	68.48	69.46	73.45	70.60	75.72	74.29	76.39	76.40	72.87	70.10	68.3	67.19	65.49	71.41
Mean	76.01	72.31	72.98	74.51	73.90	79.41	77.92	76.97	77.62	75.79	74.23	73.50	73.99	71.66	75.09
		T	G	TXG			T	G	TXG			T	G	TXG	
S.E.		0.926	2.122	4.245			0.934	2.142	4.284			0.890	2.040	4.081	
C.D. (P=0.05)		1.829	4.190	8.381			1.846	4.229	8.459			1.758	4.029	8.058	

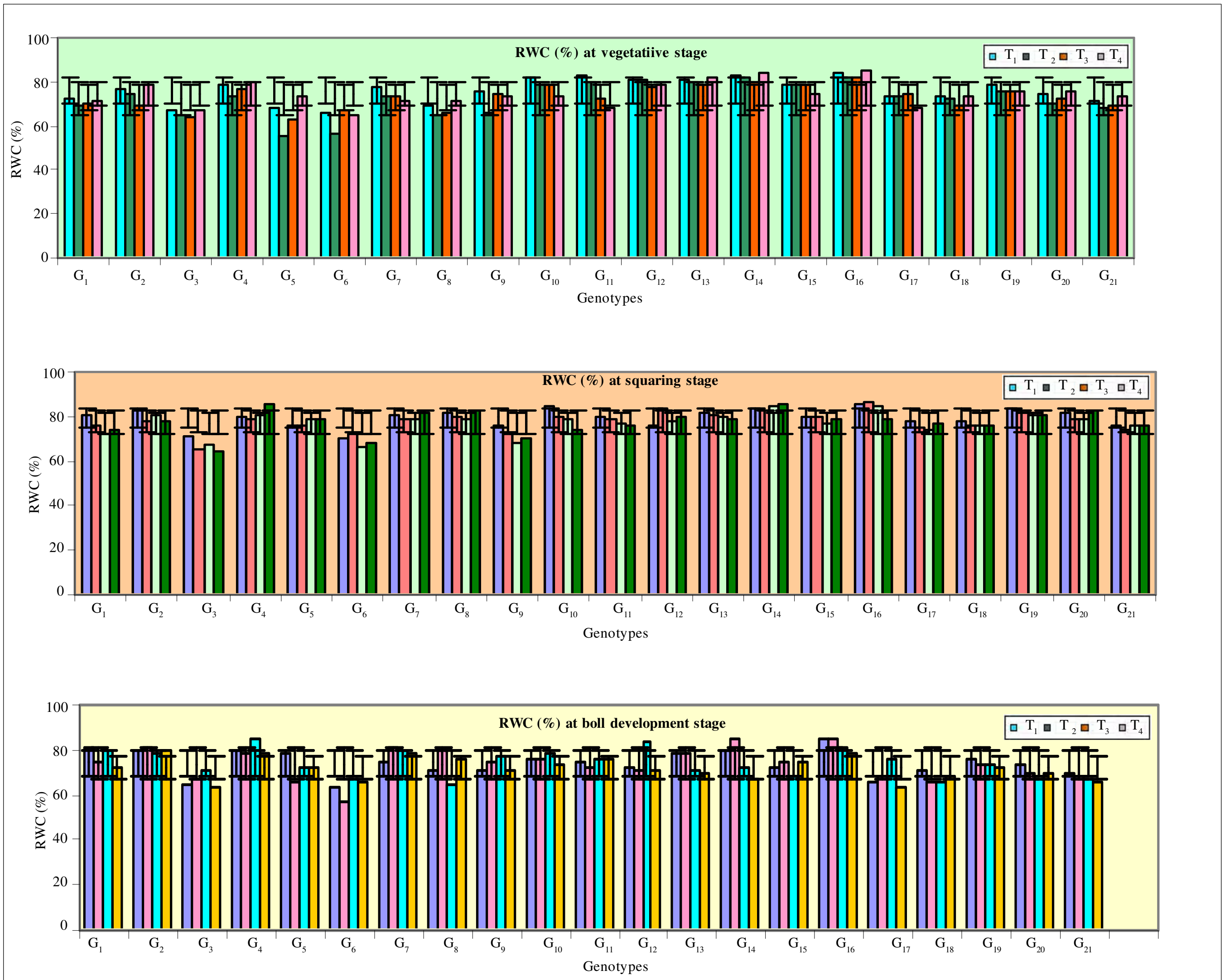

Fig 1: Effect of drought on relative water content (RWC %) at different stages of cotton in F_1, F_2, back crosses along with parents

exhibited the highest seed cotton yield of 92.59. Maximum number of flowers and bolls produced were found to be highest in KC2, AS2 and MCU13 followed by Suvin, AS1 and KC3 in parental genotypes. According to Anderson (1972), water deficit at flowering and pollination (60-70 DAS) even for a short period resulted in an irreversible damage to plant and lowered the yield. Later experiments conducted by Singh and Sahay (1992) also supported this view. Seed cotton yield ultimately is the result of plant population, photosynthetic ability of the plants in community, number of flowers and number of bolls. Yield was remarkably reduced when stress was imposed at squaring stage. Earlier report also indicated that the most critical phenophase for water stress in cotton is flowering (Singh and Sahay, 1992).

Drought is a multifaceted parameter influenced both by the genotypes as well as the environment. Drought tolerant mechanism is by and large much complicated and deserves to be quantified. In this direction an attempt was made to categorized drought tolerance in the cotton genotypes studied. From the perusal of the data (Table 3 and 4) it is seen that the genotype KC 2 had the highest mean value of drought tolerant index in relative water content (41.23) followed by AS 2 (40.91). KC2 x MCU 13 (41.13 in F_1; 41.24 in F_2). The cross KC 2 x JKC 770 recorded the highest value of drought tolerant index in RWC. Here KC 2 x JKC 770 recorded the lowest mean value of drought tolerant index in seed cotton yield. Among the genotypes Surabhi which was susceptible for water stress recorded the lowest mean value (30.45 and 35) for drought tolerant index in RWC and seed cotton yield irrespective of the treatments.

Table 2: Effect of drought on yield components of cotton in F_1, F_2, back crosses along with parents

Stages / Genotypes	Number of flowers per plant					Seed cotton yield (g pl^{-1})				
Parents	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean
MCU 13	52.8	49.5	46.9	48.6	49.5	108.23	94.59	85.45	88.27	96.09
AS 2	45.7	44.4	41.2	42.5	43.5	126.43	112.34	94.82	107.29	110.22
JKC 770	38.3	26.1	22.6	24.1	27.8	103.68	95.48	77.29	86.3	90.69
KC 2	73.2	62.1	51.5	56.2	60.3	133.16	123.16	108.17	128.32	120.28
AS 1	57.6	51.3	46.6	49.4	51.2	118.63	110.35	93.76	99.59	105.58
Surabhi	44.2	42.6	41.3	43.4	42.6	93.6	86.9	62.9	78.34	80.44
KC 3	48.9	46.5	43.2	44.8	45.9	102	96.4	89.76	95.2	95.5
Suvin	59.6	55.5	52.5	54.2	54.8	102	96.4	89.76	95.2	95.5
F_1 hybrids										
AS1 x Suvin	37.5	35.5	33.6	35	35.40	99.96	83.27	73.1	70.38	81.68
KC 2 x MCU 13	63.3	52.7	45.7	48.9	52.65	144.824	88.39	95.33	120.29	112.21
AS 2 x MCU 13	26.8	26	22.7	25	25.13	68.432	64.29	57.33	61.21	62.82
KC 2 x JKC 770	42.8	41.7	40.7	41.5	41.68	92.778	79.39	68.34	72.29	78.2
F_2'S										
KC 2 x MCU 13	55.3	49.6	46.1	48.2	49.8	157.973	121.23	116.38	120.38	128.99
AS 3 x JKC 770	33.8	32.3	28.9	31.2	31.55	58.045	42.66	35.34	49.72	46.44
AS 2 x MCU 13	34.5	33.1	29.3	31.2	32.03	89.11	60.72	54.22	63.54	68.01
KC 2 x JKC 770	36.1	35.2	31.7	32.9	33.98	69.09	55.28	45.23	54.46	56.25
AS 1 x Suvin	54.7	54.2	49.5	52.6	52.75	140.008	99.82	103.29	122.26	116.28
Back crosses										
(AS2xMCU13) x MCU13	37.1	35.2	33.2	34.1	34.90	71.968	66.23	65.29	66.39	67.47
(KC2xMCU13) x KC2	24.4	23	21.2	21.6	22.55	81.263	60.38	62.28	57.19	65.28
(AS2xMCU13) x AS2	39.6	37.4	36.2	26.9	35.03	65.8	58.92	42.1	55.1	55.48
(KC2xMCU13) x MCU13	57.9	56.4	53.2	53.8	55.33	108	92.88	78.36	85.12	92.59
Mean	45.91	42.4	38.94	40.29	41.83	101.67	85.19	76.12	84.61	86.95
	T	G	TXG			T	G	TXG		
S.E.±	1.584	0.691	3.198			3.632	1.585	7.264		
C.D. (P=0.05)	3.127	1.365	6.255			7.171	3.129	14.342		

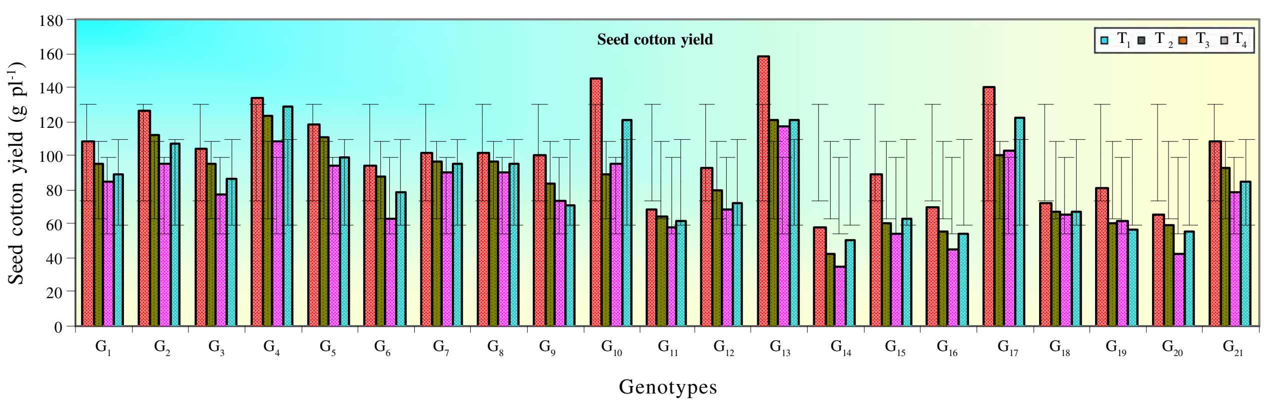

Fig 2: Effect of drought on yield components of cotton in F_1, F_2, back crosses along with parents

Table 3 : Drought tolerance index in relative water content at squaring stage

Parents	DTI at vegetative stress	DTI at squaring stress	DTI at boll development stress	Mean
MCU 13	0.97	0.92	0.95	0.95
AS 2	1.02	1.05	1.02	1.03
JKC 770	0.74	0.76	0.73	0.74
KC 2	1.01	1.02	1.08	1.04
AS 1	0.92	0.95	0.95	0.94
Surabhi	0.80	0.74	0.76	0.77
KC 3	1.01	1.01	1.05	1.02
Suvin	1.03	1.03	1.08	1.05
F_1 hybrids				
AS 1 x Suvin	0.88	0.83	0.85	0.85
KC 2 x MCU 13	1.07	1.05	0.99	1.04
AS 2 x MCU 13	1.00	0.98	0.97	0.98
KC 2 x JKC 770	1.01	0.95	0.97	0.98
F_2'S				
KC 2 x MCU 13	1.05	1.04	1.03	1.04
AS 3 x JKC 770	1.09	1.11	1.13	1.11
AS 2 x MCU 13	1.01	0.96	0.99	0.99
KC 2 x JKC 770	1.18	1.15	1.08	1.13
AS 1 x Suvin	0.92	0.92	0.95	0.93
Back crosses				
(AS2 x MCU13) x MCU 13	0.94	0.93	0.94	0.94
(KC2 x MCU13) x KC 2	1.09	1.07	1.07	1.08
(AS2 x MCU13) x AS 2	1.02	1.01	1.07	1.03
(KC2 x MCU13) x MCU 13	0.89	0.92	0.92	0.91
Mean	0.97	0.92	0.95	0.95

Table 4 : Drought tolerance index in seed cotton yield

Parents	DTI at vegetative stress	DTI at squaring stress	DTI at boll development stress	Mean
MCU 13	0.99	0.89	0.92	0.94
AS 2	1.37	1.16	1.31	1.28
JKC 770	0.96	0.78	0.87	0.87
KC 2	1.59	1.39	1.65	1.54
AS 1	1.27	1.08	1.14	1.16
Surabhi	0.79	0.57	0.71	0.69
KC 3	0.95	0.89	0.94	0.93
Suvin	0.95	0.89	0.94	0.93
F_1 hybrids				
AS 1 x Suvin	0.81	0.71	0.68	0.73
KC 2 x MCU 13	1.24	1.34	1.69	1.42
AS 2 x MCU 13	0.43	0.38	0.41	0.40
KC 2 x JKC 770	0.71	0.61	0.65	0.66
F_2'S				
KC 2 x MCU 13	1.85	1.78	1.84	1.82
AS 3 x JKC 770	0.24	0.20	0.28	0.24
AS 2 x MCU 13	0.52	0.47	0.55	0.51
KC 2 x JKC 770	0.37	0.30	0.36	0.35
AS 1 x Suvin	1.35	1.40	1.66	1.47
Back crosses				
(AS2 x MCU13) x MCU 13	0.46	0.45	0.46	0.46
(KC2 x MCU13) x KC 2	0.47	0.49	0.45	0.47
(AS2 x MCU13) x AS 2	0.38	0.27	0.35	0.33
(KC2 x MCU13) x MCU 13	0.97	0.82	0.89	0.89
Mean	0.84	0.75	0.83	0.81

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