한작지(Korean J. Crop Sci.), 55(2): 91~97(2010)

Effects of Planting Dates and Mulch Types on the Growth, Yield and Chemical Properties of Waxy Corn Crosses Sonjajang×KNU-7 and Asan×KNU-7

Souliya Souvandouane, Manuel Esguerra, Kyu Hong Heo, Cyren M. Rico, and Sang Chul Lee[†]

Division of Applied Plant Biosciences, College of Agriculture and Life Sciences, Kyungpook National University, Daegu, 702-701, Korea

ABSTRACT The growth, yield and chemical properties of waxy corn Sonjajang×KNU-7 and Asan×KNU-7 planted in different dates and mulch types in a converted paddy field was investigated. Experiment was carried out in a randomized complete block design in a split split-plot arrangement with four replications. Planting dates (D) [May 16 (D1, early), June 1 (D2, middle), June 6 (D3, late)] represented main plots, plastic mulch (M) [(BM, black mulch; TM, transparent mulch)] for subplots while waxy corn crosses [Sonjajang×KNU-7 ('Sonja') and Asan×KNU-7 ('Asan')] for sub-subplots. Results showed that D had a significant effect on growth characters except emergence, ear quality except ear diameter, and yield whereas M showed significant effect on growth characters only. Superior growth and ear quality performance were recorded in D1 and BM. In terms of crosses, 'Sonja' had better growth performance than 'Asan' regardless of D and M, but performed better at D1 and BM. Highest yield was obtained in D1 for BM (2,131 kg $10a^{-1}$) and TM (1,655 kg $10a^{-1}$) but no significant difference in the yield across V was recorded. In terms of starch and sugar contents, a decreasing trend was observed from D1 to D3 regardless of M and V.

Keywords : black plastic mulch, converted paddy field, corn, transparent plastic mulch, variety

Corn remains one of the most important and highest yielding crops in the world. In Asia, corn production increased from 87 million tons in 1980 to 167 million tons in 1999 whereas planting area increased from 37.6 million ha to 44.5 million ha in the same period (Park, 2001). In Korea, corn is a profitable crop that gives higher net profit than rice and soybeans. Green corn registered a per area net income of four times higher than rice and nine times higher than soybean. Due to higher net income coupled with increased demands and land use change, corn is now being extensively cultivated in converted paddy fields. Thus, in 2002 over 1,905 ha of paddy fields have been converted for growing upland crops which had increased to about 7,000 ha in 2004 (Kim *et al*., 2004). Soil in converted paddy fields that are used to produce upland crops have unique physical and chemical properties engendered by their transitional status (Kleinhenz, 1996; Takahashi and Toriyama, 2004). It can affect corn cultivation by waterlogging problems which reduces the uptake of oxygen and certain nutrients from the soil (Armstrong, 1978).

Kwabiah (2004) showed that growing conditions can be manipulated by planting at an early time and using plastic mulch. Phipps (1994) reported that plastic mulching could be effective in improving the yield, quality and reliability of the crop in marginal climatic area for growth of maize. Manipulating early season soil temperature by plastic mulching has improved the yield and quality of sweet corn (Felcyzynski, 1994), grain (Hanras, 1979) and forage maize (Van der werf, 1993; Nakui *et al*., 1995; Keane, 2003). Yield increase of 2 to 4 tons dry matter ha^{-1} and a proportional increase in dry matter content of 0.03-0.06 have been reported from experiment with plastic mulches in a number of Northern European countries (Madsen, 1992) and Northern Japan (Nakui *et al*., 1995). Thus, this experiment was conducted to investigate the effects of D and M on the growth, yield and chemical properties of waxy corn Sonjajang×KNU-7 and Asan×KNU-7 in a converted paddy field.

MATERIALS AND METHODS

Site description and cultural management

The experiment was conducted at Kyungpook National University (KNU) Agricultural Research Station in Gunwi

[†]Corresponding author: +82-53-950-5713
(E-mail) leesc@knu.ac.kr
<Received April 13, 2009>

in the summer season of May to September 2007. The field was a converted paddy field and was used for corn production in the previous planting season. Soil analysis showed a soil pH (1:5) of 5.7, and organic matter, P_2O_5, contents of 2 g/kg, 371 mg/kg, respectively. Soil K^+, Ca^{++} and Mg^{++} were 0.2, 3.8 and 1.4 cmol/kg, respectively. Table 1 presents the meteorological data.

The field was plowed once and harrowed twice two weeks before planting. Fertilizer application rate was 150 kg N, 130 Kg P_2O_5 and 130 Kg K_2O per ha. Half of the nitrogen requirement was applied as basal dressing before planting and the rest as top dressing during 7 to 8th leaf stage. P_2O_5 and K_2O were applied as basal dressing before planting. Plastic mulch sheets of 1.35 m wide were laid on soil 7 days before planting to allow time for soil warming, The edges of plastic mulches were pressed into the soil making the space between the rows reduced to 0.52 m wide.

Planting was done on May 16, June 1 and June 6, 2007. Corn seeds were manually sown to a depth of 50 mm at a planting space of 60 cm between rows and 25 cm between hills giving a plant population of 66,666 plants ha^{-1}. Two seeds were sown per hill and thinned to one plant at 5 to 6th leaf stage. Empty or ungerminated holes were replaced.

Plant growth and yield measurements

The data were collected from two central rows. Emergence rate was determined before thinning out the extra plants by direct counting of germinated seedling of each replication divided by the number of seeds sown. Growth parameters namely plant height (from the base of the plant to the node of flag leaf), number of leaves, and shoot dry weights were collected ten days after tasselling. Dry shoot weight was determined by cutting the plant at ground level then chopped, oven dried at 65ºC and weighed after 3 days. The ear of waxy corn was harvested 30 days after silking (Kim *et al.*, 1999). Marketable ears with shelling percentage more than 80% were harvested and recorded as number of ears per plant. All harvested ears were used in measuring bare ear length, ear diameter, 100-grain weight, and fresh ear weight. Ear characters and fresh ear yield were measured immediately after harvest. Grain weight was determined by adjusting grain moisture to 15%. Grains were manually removed from the cobs, weighed and subsamples of approximately 0.25 kg per plot were weighed fresh, oven- dried to constant weight at 65ºC to determine the water content.

Starch and sugar analyses

Starch and sugar were extracted according to the methods of Jorge *et al*., (1976) with some modifications. Fresh ear from each treatment were stored in deep freezer (-70C) immediately after harvesting. Frozen kernels (2 g) taken from the central portion of the ear were ground with 30 ml of boiling 80% (v/v) ethanol and homogenized by centrifuging at 13,000 rpm for 6 min at 20°C. The process was repeated twice and the supernatant was collected each time. The supernatant was evaporated at 85°C until most of the alcohol was removed then diluted to 50 ml solution with distilled water. The remaining pellets after third centrifugation was resuspended in 30 ml 95% (v/v) DMSO, heated at 60°C for 20 min with stirring and diluted to a final volume of 100 ml using distilled water. The starch and total sugar was determined by enzymatic bio-analysis and spectrophotometer determination using commercial test kit (BOEHRINGE MANNHEIM).

Table 1. Metrological data in Gunwi.

Meteorological parameters	May	June	July	August	September	Mean
Maximum temperature (ºC)	25.9	28.8	28.9	31.7	26.4	28.3
Minimum temperature (ºC)	9.7	15.6	19.8	22.2	17.6	17.0
Average temperature (ºC)	17.5	21.9	23.8	26.2	21.4	22.2
Precipitation (mm)	90.0	163.5	172.5	278.0	403.5	221.5
Sunshine (h)	222.1	156.0	101.4	143.1	82.7	141.1

Source: Korea Metrological Administration, 2007

Statistical analysis

The experiment was carried out in a randomized complete block design in a split split-plot arrangement with four replications. Planting dates (D) [May 16 (D1, early), June 1 (D2, middle), June 6 (D3, late)] represented main plots, plastic mulch (M) (BM, black mulch; TM, transparent mulch) for subplots while waxy corn crosses [Sonjajang×KNU-7 ('Sonja') and Asan×KNU-7 ('Asan')] for sub-subplots. Data were analyzed using the GLM procedure of SAS (SAS Institute, Inc., Cary, NC, USA).

RESULTS

Treatment effects on measured parameters

All treatments showed significant effects on the growth parameters except for the effect of V on emergence rate (Table 2). The interaction of D and M was significant in all growth parameters except for shoot weight and emergence rate. For ear quality parameters, only D and V had significant effect on all parameters except for ear diameter and ear length, respectively (Table 3). M did not show significant effect on any of the ear quality parameters while D×M had significant effect only in ear diameter. In case of yield and chemical composition parameters, D and V had significant effect on all parameters while M had significant effect only on the total yield and starch composition (Table 4). The D×M did not significantly affect the starch content.

Effects on growth characters

All treatments showed significant effects on the growth parameters except for effect of V on emergence rate (Table 2). In agreement with this, result revealed that growth parameters had significant differences between D (Table 5). Growth parameters in D1 in both BM and TM showed

Table 2. ANOVA of growth parameters of waxy corn affected by the number of cultural practices.

Sources of variation	df	Plant Height	Number of Leaves	Shoot weight	Emergence (%)	Days to Tasseling
Date (D)	2	**	**	*	**	**
Mulch (M)	1	**	**	**	*	**
DxM	2	**	**	ns	ns	**
Variety (V)	1	**	**	**	ns	**
DxV	2	**	*	**	ns	ns
MxV	1	*	*	*	*	ns
DxMxV	2	*	ns	ns	ns	ns
Total						

*,** Significant at P<0.05 and P<0.01, respectively.

Table 3. ANOVA of ears characters of waxy corn affected by the number of cultural practices.

Sources of variation	df	No. ears/plant	Ear Length	Ear diameter	Ear Weight
Date (D)	2	**	**	ns	**
Mulch (M)	1	ns	ns	ns	ns
DxM	2	ns	ns	**	ns
Variety (V)	1	*	ns	**	*
DxV	2	ns	**	ns	ns
MxV	1	ns	**	ns	*
DxMxV	2	ns	ns	ns	ns
Total					

*,** Significant at P<0.05 and P<0.01, respectively.

Table 4. ANOVA of grain weight, yield and chemical components of waxy corn affected by the number of cultural practices.

Sources of variation	df	100-grain weight	Total ear yield	Starch (%)	Sugar (%)
Date (D)	2	*	**	*	**
Mulch (M)	1	ns	*	**	ns
DxM	2	*	*	ns	**
Variety(V)	1	**	*	**	*
DxV	2	ns	ns	ns	*
MxV	1	ns	*	ns	ns
DxMxV	2	*	ns	ns	*
Total					

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

Table 5. Differences in plant height (PH), number of leaves (NL), shoot weight (SW), emergence rate (E) and date to tasselling (DT) of two new waxy corn cultivars across varieties and mulching type in three planting dates in Gunwi, Kyungbuk, Korea.

	Black mulch					Transparent mulch				
	PH (cm)	NL (no.)	SW (g)	E (%)	DT (days)	PH (cm)	NL (no.)	SW (g)	E (%)	DT (days)
16 May PDT										
Sunja	202§a†	19a	1017a	60a	66a	194a**	15a**	808a**	57a^{ns}	61a**
Asan	181b	14b	317b	73a	59b	144b**	12b**	252b^{ns}	48a^{ns}	50b**
Mean	192x‡	16x	667x	67y	63x	169x	14x	530x	53y	56y
1 June PDT										
Sunja	188a	16a	792a	48a	62a	178a^{ns}	14a^{ns}	657a^{ns}	34a**	62a^{ns}
Asan	183a	13b	292b	48a	51b	165a**	11b*	350b^{ns}	33a**	51b^{ns}
Mean	185y	15y	542y	48z	56y	172x	13x	513x	34z	57x
6 June PDT										
Sunja	167a	14a	517a	90a	62a	159a^{ns}	13a^{ns}	458a^{ns}	95a^{ns}	56a**
Asan	149b	11b	417a	95a	51b	148a^{ns}	11b^{ns}	333a^{ns}	93a^{ns}	45b**
Mean	158z	12z	467y	93x	57y	154y	11y	396y	94x	51z

^{ns} Between mulching types, not significantly different at $P<0.05$.
*,** Between mulching types, significant at $P<0.05$ and $P<0.01$, respectively.
† Within varieties, same letters are not significantly different at $P<0.05$ level by DMRT.
‡ Between planting dates, same letters are not significantly different at $P<0.05$ level by DMRT.
§ All values are mean of 15 samples and 4 replications.

higher values compared to D2 and D3. Plant height, numbers of leaves, shoot weight, and days to tasselling (192 cm, 16, 667 g, and 63 days, respectively) in D1 under BM had higher values than in D3 (158 cm, 12, 467 g, and 57 days, respectively). The same trend was observed in TM although values in D1 and D2 had similar values that were higher than those in D3.

In the case of emergence rate, D3 obtained higher value (93%) compared to those of D2 and D3 (67 and 48%, respectively). TM exhibited the same trend. This result is consistent with the highly significant effect of D on emergence rate.

Analysis between M showed lower values in most parameters under TM in D1 indicating that both V performed better when planted under BM. Plant height, number of leaves, shoot weight, and days to tasselling of 'Sonja' planted in TM decreased significantly compared to those in BM by 4, 21, 21, and 8%, respectively, whereas emergence rate did not. In the case of 'Asan' planted under TM, plant height, number of leaves, and days to tasselling decreased significantly compared to that in BM by 20, 14 and 15%, respectively, whereas shoot weight and emergence rate did not.

Analysis between V within D in both M showed that growth parameters in ‘Sonja’ had higher values than those of ‘Asan’. These results showed better performance of ‘Sonja’ compared to ‘Asan’ regardless of D and M. Results further showed that ‘Sonja’ performed better when planted at early under BM.

Effects on ear quality

ANOVA showed that D had significant effect on all parameters except for ear diameter (Table 6). The same was observed for V except for ear length while M did not show significant effect on any of the ear quality parameters. Analysis of ear characters across D in BM showed that number of ears was higher (2 pcs.) in D1 than D2 and D3 (1 pc.). Ear length and weight obtained similar values in D1 and D2 (18, 18 cm and 134, 130 g, respectively) which were higher than those of D3 (17 cm and 94 g, respectively). There was no difference in ear diameter D1, D2 and D3 (40, 39, and 38 mm, respectively). In the case of TM, same trend was observed in all parameters except for ear weight, which obtained similar values across D (122, 118 and 100 g respectively).

Analysis across V within D showed that ‘Asan’ obtained higher values than ‘Sonja’ in all parameters except for the number of ears in D1. However, there were no significant differences between V in D2 and D3. In TM, there were no significant differences between V in all D except for ear length D1 and D2 wherein ‘Sonja’ obtained higher value than ‘Asan’, and number of ears in D3 wherein ‘Sonja’ also obtained higher value than ‘Asan’.

Analysis between M also showed no significant differences in the parameters except for ear weight in ‘Asan’ in D2 and D3. These results showed that M did not affect the ear quality. Result further showed that D did not significantly affect the ear quality.

Effect on yield and chemical composition

The 1000-grain weight across D had no significant difference in both BM and TM (Table 7). The total yield across D for those planted under BM was higher in D1 (2,131 kg $10a^{-1}$) compared to those of D2 (1,333 kg $10a^{-1}$) and D3 (772 kg $10a^{-1}$). Under TM, D1 and D2 obtained similar

Table 6. Differences in number of ears (NE), ear length (EL), ear diameter (ED) and ear weight (EW) of two new waxy corn cultivars across varieties and mulching type in three planting dates in Gunwi, Kyungbuk, Korea.

Planting date treatment and cultivar	Black				Transparent			
	NE (no.)	EL (cm)	ED (mm)	EW (g)	NE (no.)	EL (cm)	ED (mm)	EW (g)
16 May PDT								
Sunja	3[§]a[†]	17a	38b	121b	2a^{ns}	18a^{ns}	38a^{ns}	122a^{ns}
Asan	2b	18b	43a	146a	2a^{ns}	17b^{ns}	41a^{ns}	123a**
Mean	2x[‡]	18x	40x	134x	2x	18x	40x	122x
1 June PDT								
Sunja	2a	18a	36a	122a	1a^{ns}	18a^{ns}	39a^{ns}	119a^{ns}
Asan	1a	17a	40a	138a	1a^{ns}	16b^{ns}	41a^{ns}	118a**
Mean	1y	18x	39x	130x	1y	17x	40x	118x
6 June PDT								
Sunja	1a	16a	39a	90a	2a^{ns}	16a^{ns}	39a^{ns}	101a^{ns}
Asan	1a	17a	41a	98a	1b^{ns}	16a^{ns}	38a^{ns}	98a^{ns}
Mean	1y	17y	38x	94y	1y	16y	40x	100x

Between mulching types, not significantly different at P<0.05.
*,** Between mulching types, significant at P<0.05 and P<0.01, respectively.
[†] Within varieties, same letters are not significantly different at P<0.05 level by DMRT.
[‡] Between planting dates, same letters are not significantly different at P<0.05 level by DMRT.
[§] All values are mean of 15 samples and 4 replications.

Table 7. Differences in 1000-grain weight (GW), total yield (Y), starch content (St) and sugar content (Su) of two new waxy corn cultivars across varieties and mulching type in three planting dates in Gunwi, Kyungbuk, Korea.

Planting date treatment and cultivar	Black				Transparent			
	GW (g)	Y (kg $10a^{-1}$)	St (%)	Su (%)	GW (g)	Y (kg $10a^{-1}$)	St (%)	Su (%)
16 May PDT								
Sunja	14§b†	2058a	70a	1.7a	17b**	2052a^ns	66a^ns	1.6a^ns
Asan	21a	2004a	77a	2.4a	20a^ns	1258a*	71a^ns	1.7a*
Mean	17x‡	2131x	74x	2.0x	18x	1655x	68x	1.6y
1 June PDT								
Sunja	18b	1378a	65a	1.7a	18a^ns	1422a^ns	54a^ns	2.0a*
Asan	24a	1288a	76a	1.6a	20a^ns	1177a^ns	81a^ns	1.8a^ns
Mean	21x	1333y	71x	1.7y	19s	1299x	67x	1.9x
6 June PDT								
Sunja	17a	801a	50a	1.7a	15b^ns	810a^ns	46a^ns	1.5b^ns
Asan	18a	742a	63a	1.8a	18a^ns	728a^ns	44a*	1.8a*
Mean	17x	772z	56y	1.7y	17x	769y	45y	1.7y

ns Between mulching types, not significantly different at P<0.05.
*,** Between mulching types, significant at P<0.05 and P<0.01, respectively.
† Within varieties, same letters are not significantly different P<0.05 level by DMRT.
‡ Between planting dates, same letters are not significantly different P<0.05 level by DMRT.
§ All values are mean of 15 samples and 4 replications.

yield (1,655 and 1,299 kg $10a^{-1}$, respectively) which was higher with that of D3 (769 kg $10a^{-1}$). Also, there were no significant differences in the yield across V. This trend was observed between V across M except for 'Asan' which recorded a yield in TM (1,258 kg $10a^{-1}$) that was lower in BM (2,004 kg $10a^{-1}$).

For chemical composition, D1 and D2 in BM obtained similar starch content (74 and 71%, respectively) which was higher than that of D3 (56%). This trend was also observed in TM wherein D1 and D2 had similar starch content (68 and 67%, respectively) which was higher than that of D3 (45%).

Sugar content in BM was similar in D2 and D3 (1.7 and 1.7%, respectively) but lower than that of D1 (2.0%). In TM, D2 obtained higher sugar content (1.9%) than those of D1 (1.6%) and D2 (1.7%).

DISCUSSIONS

Paddy field cultivation of upland crops particularly corn and soybean is now a common practice in Korea. Studies have even shown that corn (Souvanduoane *et al*., 2008) and soybean (Kim *et al*., 2004, Eun *et al*., 2007) had better growth, yield and quality when planted in the upland field. The challenge now is to achieve corn production twice a year which is only possible if planting starts early in late spring when temperature is still cold and dry.

Result showed that D had a significant effect on the growth characters except emergence, ear quality except ear diameter, and yield. The corn cultivars had superior performance at D1 than at D2 and D3. High emergence in D3 could be attributed to the higher temperature (21.9°C), which favors higher emergence of corn, than in D1 (17.5°C). These results were in agreement with similar studies wherein D also showed significant effect on corn production in temperate places (Olsen *et al*., 1990; Dale and Drennan, 1997; Easson and Fearnehough, 2000; Kwabiah 2004).

M had significant effect on the growth characters. TM has high soil heating but low heat retention capacity while BM has low soil heating and high heat retention capacity (Gilby, 1990). However, the results showed that M did not effectively increase temperature favorable for seed emergence at D1 and D2. On the other hand, BM had a positive effect on the plant growth especially in D1. This could be possibly due to much greater weed control in BM (Gilby, 1990) than in TM resulting in lesser competition for nutrients. Furthermore, M raises soil temperature by 2 to 4°C (Van der werf, 1993) or 6 to 11°C (Easson, 2000) which allows corn to grow and mature faster.

In terms of growth character, 'Sonja' had better performance than 'Asan' regardless of D and M. It also performed better when planted at D1 using BM. However, the opposite was observed in ear quality wherein 'Asan' obtained better ear quality than 'Sonja'. Also, contrary to what was observed in the growth characters, M did not show significant effect on the ear quality.

Yield was highest at D1. This was consistent with the high performance in the growth characters and ear quality. Significant differences between planting dates were more pronounced in BM than in TM. In D1 at both BM and TM, there was no significant difference in the yield between 'Asan' and 'Sonja'. 'Asan' in TM obtained lower yield than that in BM when planted at D1, but this was not observed in D2 and D3. The 1000-grain weight obtained higher value only in 'Asan' in D1 in both TM and BM.

Starch content decreased from D1 to D3 in both M. On the other hand, the sugar content did not show consistent result between D in both M.

REFERENCES

Armstrong, W. 1978. The effect of drainage treatments on cereal yield: results from experiments on clay lands. J. Agric. Sci. 91:229-235.

Dale, A.E. and D.S.H. Drennan. 1997. Transplanted maize (*Zea mays*) for grain production in southern England. I. Effects of planting date, transplant age at planting and cultivar on grain yield. The J. Agric. Sci 128 : 27-35.

Easson, D.L. and W. Fearnehough. 2000. Effect of plastic much, planting date and cultivar on the yield and maturity of forage maize grown under marginal climatic condition in Northern Ireland. Grass Forage Sci. 55: 221-231.

Eun, J.H., C.M. Rico, M.K. Kim, S. Souvandouane, T.K. Son, D.I. Shin, K.I. Chung and S.C. Lee. 2007. Yield performance and nutritional quality of 'Agakong' soybean harvested in drained-paddy and upland fields. Kor. J. Plant Res. 20(3) : 258-262.

Felcyzynski, K. 1994. Plant and soil covers in direct seeded and transplanted sweet corn. Acta Hort. 371 : 317 -319.

Gilby, G.W. 1990. Specialty horticultural films, based on polyethylenes, for greater control of the growing environment. Proc. XI International Congress on 'The use of plastics in agriculture'. New Delhi, India.

Hanras, J.C.H. 1979. Agricultural and horticultural uses for photodegrable polyethylene (LDPE) films. Plastic Culture 41 : 43-58.

Keane, G.P., J. Kelly, S. Lordan and K. Kelly. 2003. Agronomic factors affecting the yield and quality of forage maize in Ireland: Effect of plastic film system and seedling rate. Grass Forage Sci. 58 : 362-371.

Kim, I.H., S.K. Kim and S.C. Lee. 2001. Growth characters and sugar content during grain filling in new hybrid, Chalok1/Cooktail 51 corn. Kor. J. Crop Sci. 46(2) : 69-77.

Kim, S.L., K.Y. Park, Y.H. Lee and H.R. Yong. 2004. Seed quality of soybean produced from upland and drained-paddy field. Kor. J. Crop Sci. 49(4) : 309-315.

Kleinhenz, V., W.H. Schnitzler and D.J. Midmore. 1996. Diversification and transformation of Asian paddy rice fields to upland vegetable production. Entwicklung und Landlicher Raum 3 : 23-26.

Kwabiah, A.B. 2004. Growth and yield of sweet corn (*Zea mays* L.) cultivars in response to planting date and plastic mulch in a short-season environment. Sci. Hort. 102 : 147-166.

Madsen, M.B. 1992. Mulching of Maize with plastic. Tidssskrift for Planteavl 96 : 343-351.

Nakui, T., K. Nonaka, S. Hara and M. Shinoda. 1995. The effect of plastic mulch on the growth of corn plants and their TDN yield of silage in the Tokachi district. Res. Bull. Hokkaido Nat'l. Agric. Exp. Stn. 161 : 73-80.

Olsen, J.K., G.W. Blight and D. Gillespie. 1990. Comparison of yield, cob characteristics and sensory quality of six supersweet (sh2) corn cultivars grown in a subtropical environment. Australian J. Experimental Agri. 30(3) : 387-393.

Park, J.P. 2001. Corn production in Asia. Food and fertilizer technology center for Asian and Pacific region. p. 206.

Phipps, R.H. 1994. Protected maize: benefits. Farmer weekly, 120 (7), Quality Forage Suppl., 20-21.

Robinson, M. 2008. Mulches – Alternatives to peat and their use. Conference on peat alternatives. Belfast

Takahashi, T. and Toriyama, K. 2004. Method to evaluate 'Uplandization' in converted field from a paddy based on crystallinity of free iron oxides. Japan Agric. Res. Quart. 38(3) : 155-159.

Van der Werf, H.M.G. 1993. The effect of plastic mulch and greenhouse raised seedling on yield of maize. J. Agron. Crop Sci. 170 : 261-269.