Effect of Thiobencarb on Various Agronomic Traits of Rice (*Oryza sativa* L.) Cultivars

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除草劑 Thiobencarb 處理가 벼 主要形質에 미치는 影響

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ABSTRACT

This study was conducted to determine which of the different agronomic traits of rice (*Oryza sativa* L.) has greater weight in predicting thiobencarb (*S*-[(4-chlorophenyl)methyl]diethylcarbamothioate) tolerance. Differences in plant height, tiller number, culm length, panicle number, and spikelet number per panicle between tolerant and susceptible cultivars were greater at the higher herbicide rate. However, days to heading and percent filled spikelets were not affected by herbicide rate. At the higher thiobencarb rate, the coefficients for all characters except plant height, tiller number, and percent filled spikelets were significant. Spikelet number per panicle and panicle number which had positive significant coefficients at both concentrations are the most useful indicators of total filled spikelets.

Key words : Herbicide tolerance, selection, agronomic traits, rice.

INTRODUCTION

Selection procedures are crucial in screening of cultivars for tolerance to herbicides. The ideal basis for selection considers all information about the individual's characters.

In most crops, the common indices used for selection are yield components. The relative contribution of the different components are often measured by yield correlations, multiple regression, discriminant analysis, or by path coefficient analysis. In rice, analysis by discriminant function showed that traits such as the number of effective tillers and grains per panicle were more effective in selecting for yield compared with other components(11). Chaudhury et al.(2) observed that grain number and 1,000-grain weight had the highest association with yield and were the most useful and reliable criteria.

Rice is susceptible to thiobencarb from the seedling to the coleoptile stages at herbicidal rates and gains tolerance as it grows older (7). The herbicide induces various morphological changes of monocot plants such as barnyardgrass (*Echinochloa crus-galli* (L.) Beauv.) in which roots are little affected, the mesocotyl is inhibited in its elongation, and the leaves turn dark-green, remain folded within the coleoptile and burst out from the side of the coleoptile (1).

Differential cultivar responses to different herbicide rates have been reported by several workers(8, 9, 10). Shin et al. (10) reported that there were greater differences in thiobencarb phytotoxicity between tolerant and susceptible cultivars as the herbicide concentration increased.

This experiment was conducted to determine which of the different agronomic traits such as plant height, tiller number, days to heading, panicle number, spikelet number, and phenotypic acceptability had the

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greatest weight in predicting herbicide tolerance in terms of total filled spikelets and to compare responses of tolerant and susceptible cultivars.

MATERIALS AND METHODS

A silty clay soil with pH 6.5, 1.53% organic carbon, 0.152% total nitrogen, and a cation exchange capacity of 40.2 meq/100 g was used for this experiment.

Seeds of 19 tolerant and 25 susceptible cultivars which were selected from previous research (10) were soaked for 24 h and incubated for 48 h before seeding. Ten germinated seeds per cultivar were planted in plastic buckets (30 cm in diameter) filled with soil. Water was introduced into the buckets to a depth of 2 to 3 cm just before herbicide application.

The number of seedling was reduced to four of similar height and general appearance before herbicide application. Appropriate amounts of concentrated thiobencarb which had been diluted with water to give volumes equivalent to 70 and 100 ml/bucket, respectively, were applied at 2.5 and 3.5 kg ai/ha 6 days after seeding (DAS) into the water at the edges of the buckets.

Urea was applied at 140 kg N/ha ; 60 kg was applied 1 week after seeding ; 40 kg at 40 DAS ; and 40 kg at panicle initiation. Insecticides were applied when necessary to control insect pests.

Treatments were replicated three times and untreated controls were provided for comparision.

Plant height, tiller number, days to heading, culm length, phenotypic acceptability, panicle number, and spikelet number per panicle were measured based on the Standard Evaluation System (SES) of the International Rice Research Institute (5) and all data were expressed as % of control. Plant height was taken from the soil surface to the tip of the longest leaf or panicle 7, 21, 42 days after treatment (DAT) and at harvest. The numbers of days to 50% emergence of all panicles was recorded. The score for phenotypic acceptability was based on visual estimation of plant stature compared to the untreated control plants. To determine spikelet number, one panicle was taken from each hill. Total spikelet number, filled spikelets and percent filled spikelets were determined.

The total filled spikelets response function was determined to find out which of the various agronomic traits used had the greatest weight in predicting tolerance to thiobencarb in terms of total filled spikelets. For this analysis, all the data were converted to % of control.

In order to determine the weight of the various agronomic traits, a multiple regression equation was fitted to the data using IRRISTAT (6). As a measure of herbicide tolerance, the total number of filled spikelets was used as the dependent variable. The independent variables were data from all of the agronomic traits. The following equation was used.

$$Y = a + b1\ PLHT + b2\ TINO + b3\ DATH + b4\ CULT + b5\ PANN + b6\ SPPA + b7\ PEFS + b8\ PHAC$$

where the b's are the regression coefficients which estimate the weight of each trait and

Y = total number of filled spikelets
PLHT = plant height (21 DAT)
TINO = tiller number (28 DAT)
DATH = days to heading
CULT = culm length
PANN = panicle number per hill
SPPA = spikelet number per panicle
PEFS = percent filled spikelets
PHAC = phenotypic acceptability

A path coefficient analysis was conducted to determine the relationship between the different agronomic traits which showed significant effects on total number of filled spikelets based on a "t" test for each regression coefficient. The traits selected for the analysis were days to heading (DATH), culm length (CULT), panicle number per hill (PANN), spikelet number per panicle (SPPA) and phenotypic acceptability (PHAC).

The path coefficient for each trait was calculated using the equations of Dewey and Lu (3) and Hazel (4). The path diagram is shown in Figs. 3 and 4. The path coefficients were solved using the following simultaneous equations :

(1) $r_{17} = p_1 + r_{12}p_2 + r_{13}p_3 + r_{14}p_4 + r_{15}p_5$

(2) $r_{27} = r_{12}p_1 + p_2 + r_{23}p_3 + r_{24}p_4 + r_{25}p_5$

(3) $r_{37} = r_{13}p_1 + r_{23}p_2 + p_3 + r_{34}p_4 + r_{35}p_5$

(4) $r_{47} = r_{14}p_1 + r_{24}p_2 + r_{34}p_3 + p_4 + r_{45}p_5$

(5) $r_{57} = r_{15}p_1 + r_{25}p_2 + r_{35}p_3 + r_{45}p_4 + p_5$

and $P_6 = [1-(p_1^2 + p_2^2 + p_3^2 + p_4^2 + p_5^2 + 2(r_{12}p_1p_2 + r_{13}p_1p_3 + r_{14}p_1p_2 + r_{15}p_1p_5 + r_{23}p_2p_3 + r_{24}p_2p_4 + r_{25}p_2p_5 + r_{34}p_3p_4 + r_{35}p_3p_5))]^{\frac{1}{2}}$

The simultaneous equations (1, 2, 3, 4, and 5) were transformed into the following matrix form :

$$\begin{matrix} r_{17} \\ r_{27} \\ r_{37} \\ r_{47} \\ r_{57} \end{matrix} = \begin{matrix} r_{11} & r_{12} & r_{13} & r_{14} & r_{15} \\ r_{21} & r_{22} & r_{23} & r_{24} & r_{25} \\ r_{31} & r_{32} & r_{33} & r_{34} & r_{35} \\ r_{41} & r_{42} & r_{43} & r_{44} & r_{45} \\ r_{51} & r_{52} & r_{53} & r_{54} & r_{55} \end{matrix} \quad \begin{matrix} p_1 \\ p_2 \\ p_3 \\ p_4 \\ p_5 \end{matrix}$$

or

$[A] = [B]\ [p]$

The path coefficients (p's) were calculated by solution of the matrix

$[p] = [B]^{-1}\ [A]$

The inverse matrix [B] was calculated and then multiplied by the [A] matrix in order to produce the path coefficients.

RESULTS AND DISCUSSION

Effect of Thiobencarb on Various Agronomic Traits

Rice cultivars which had total filled spikelets per hill greater than 75% of the untreated check were considered to be tolerant to thiobencarb when 3.5 kg ai/ha was applied. Cultivars having greater than 50% reduction in total filled spikelets per hill were regarded as being susceptible to the herbicide.

Mean plant height of the tolerant cultivars was less inhibited than that of the susceptible ones, regardless of the herbicide concentration and the sampling time (Fig. 1). The degree of reduction in plant height decreased with the tolerant cultivars with delay in sampling for both herbicide rates. However, with the susceptible cultivars that were treated with 3.5 kg ai/ha, the degree of reduction increased up to 21 DAT and thereafter it decreased because of recovery from the initial phytotoxic effect. The difference in plant height between the tolerant and the susceptible cultivars was greatest at 21 DAT.

At the higher thiobencarb rate, the greatest inhibition in tiller number was observed at 28 DAT with both the tolerant and susceptible cultivars although there was a marked difference in the degree of inhibition between them (Fig. 1).

The growth duration of the susceptible and tolerant cultivars was slightly delayed by thiobencarb applica-

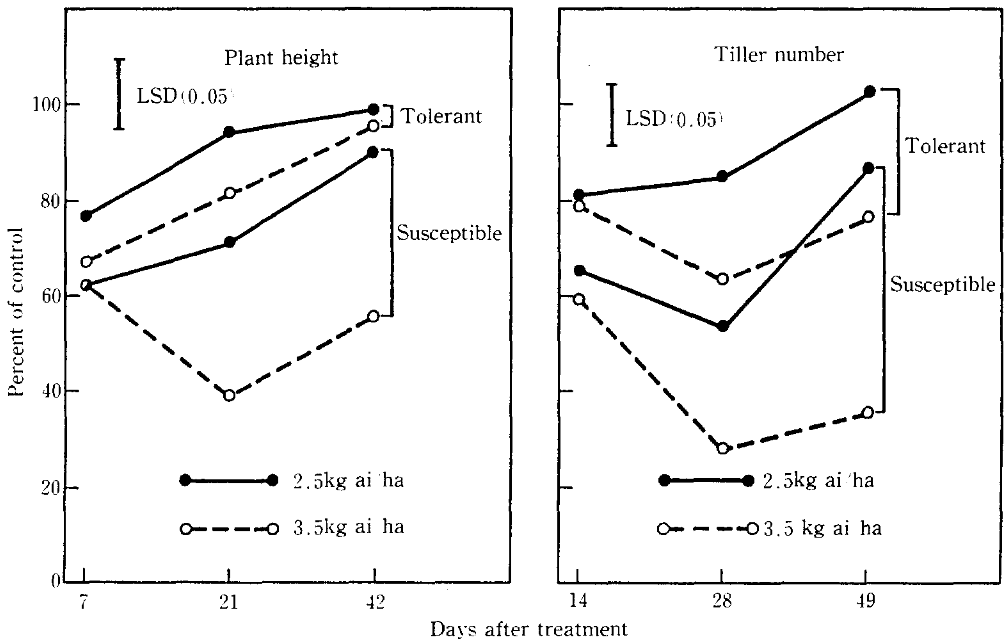

Fig. 1. Plant height and tiller number of tolerant and susceptible rice cultivars as affected by different thiobencarb rates.

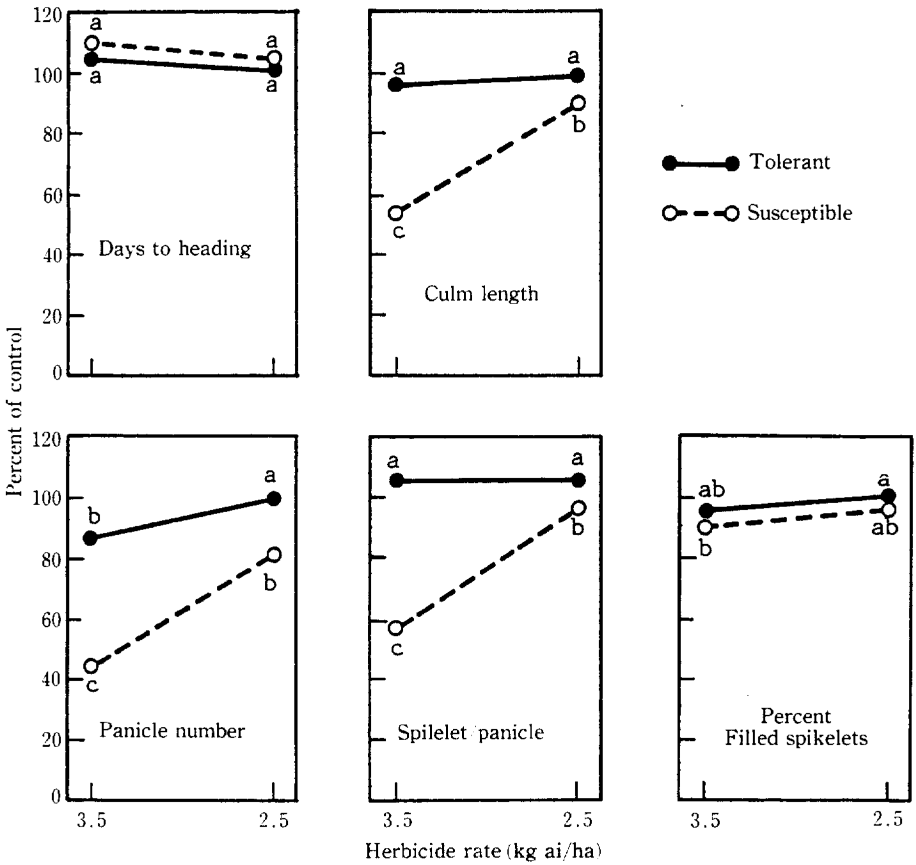

Fig. 2. Various agronomic traits of tolerant and susceptible rice cultivars as affected by different thiobencarb rates.

tion although delay in heading was greater with the susceptible cultivars than the tolerant ones (Fig. 2).

Reductions in culm length and panicle number were significantly greater with the susceptible cultivars than with the tolerant and differences were greater at the higher rate (Fig. 2).

Spikelet number per panicle was not affected by the herbicide rate for the tolerant cultivars but significant reduction in spikelet number was observed at the higher rate for the susceptible cultivars (Fig. 2).

There was little difference in the percent filled spikelets between the tolerant and the susceptible cultivars. There was a slightly greater decrease at the higher herbicide rate with the susceptible cultivars (Fig. 2).

Thiobencarb is known as a growth inhibition type herbicide and shows various morphological changes depending on the herbicide rate (1). The leaves of susceptible cultivars remain folded within the coleoptile and burst out from the side of coleoptile resulting in retardation of rice growth at the early growth stage. In addition, thiobencarb inhibits formation of new leaves of plants at herbicidal rates and exhibits a high inter-genus selectivity (1). Differences in the various agronomic traits between the tolerant and the susceptible cultivars in this experiment may be attributed to inherent morphological or physiological characteristics, biochemical differences among cultivars, or to differential rates of uptake and translocation of the herbicide. There were greater responses to the herbicide at the higher rate.

Weight of Various Agronomic Traits Affecting Total Filled Spikelets

The coefficient of determination r^2 was 0.98 and 0.99 at 2.5 and 3.5 kg ai/ha thiobencarb, respectively,

Table 1. Multiple regression of agronomic traits as affected by different thiobencarb rates[1].

Explanatory variable	Regression coefficient (b's)			
	2.5 kg ai/ha	3.5 kg ai/ha		
	Non-logarithmic	Non-logarithmic		Logarithmic
PLHT	-0.029ns (0.101)	-0.035ns (0.071)	-0.022ns (0.217)	0.082ns (0.208)
TINO	0.043ns (0.053)	0.055ns (0.053)	-0.013ns (0.163)	-0.140ns (0.114)
DATH	0.078ns (0.292)	0.344* (0.131)	-0.803* (0.339)	-2.422** (0.782)
CULT	0.0003ns (0.092)	-0.173** (0.047)	0.127ns (0.134)	0.395** (0.137)
PANN	0.934** (0.054)	0.789** (0.045)	1.116** (0.123)	1.325** (0.135)
SPPA	0.963** (0.050)	0.738** (0.044)	–	–
PEFS	-0.043ns (0.058)	-0.059ns (0.038)	0.278** (0.099)	0.598** (0.126)
PHAC	-0.005ns (0.134)	-0.164* (0.068)	-0.044ns (0.206)	0.033ns (0.089)
r^2	0.98	0.99	0.90	0.93
a	-93.413	-66.902	36.798	5.386
F	193.54**	366.59**	40.89**	61.80**

[1] Values in the first row of each variable refer to the regression coefficient. ns=non-significant, *=significant at 5% level, **=significant at 1% level ; Values in the second row (in parenthesis) refer to standard error.

indicating that 98 or 99% of the variation in total filled spikelets is accounted for by the independent traits measured (Table 1). The regression equations for 2.5 and 3.5 kg ai/ha thiobencarb were significant at the 1% level.

At 2.5 kg ai/ha thiobencarb, only the regression coefficients for panicle number and spikelet number per panicle were significant (Table 1). This means that either the other traits did not affect the total number of filled spikelets or the relationship between these traits and the total number of filled spikelets was not linear.

At 3.5 kg ai/ha thiobencarb, the coefficients of all characters except plant height, tiller number, and fertility were significant. These results suggest that plant height, tiller number, and percent filled spikelets are not good indicators of total filled spikelets and screening for cultivar tolerance to thiobencarb will be more effective at higher herbicide rate. This is supported by the results shown in Figs. 1 and 2 that the higher herbicide rate gave rise to greater cultivar differences in all the characters between the tolerant and susceptible cultivars.

The negatve coefficient of phenotypic acceptability is due to the scoring method used. Good phenotypes or tolerant cultivars have low scores while poor phenotypes or susceptible cultivars have high scores. The number of days to heading is expected to have a negative effect on total filled spikelets and the culm length is expected to have a positive effect on total filled spikelets based on the results in Fig. 2. Thus, tolerant cultivars have a greater culm length and a lower number of days to heading than susceptible cultivars as expressed as % of control. However, the coefficient of days to heading was positive while that of culm length was negative. This may be due to the consequence of a multicollinearity problem in which culm length is highly correlated with spikelet number per panicle and indicates that the linear regression equation used is not adequate to fully capture the effects of various traits on the total number of filled spikelets. When the spikelet number per panicle was dropped from the equation, the coefficient of days to heading was negative and significant and that of culm length was positive but not significant (Table 1). In a logarithmic form, a positive significant coefficient of culm length was observed.

Spikelet number per panicle and panicle number had positive significant coefficients at both rates. These traits are, therefore, the most useful indicators of total filled spikelets.

Path Coefficient Analysis

Spikelet number per panicle had the highest correlation with total number of filled spikelets at both herbicide rates (Figs. 3 and 4). Panicle number also had high a correlation with total number of filled spikelets. The negative coefficient of phenotypic acceptability was due to the scoring method used and the negative coefficient of days to heading was expected from the results shown in Fig. 2. Phenotypic acceptability is associated with culm length and days to heading (r=-0.588, and 0.651 at 2.5 kg ai/ha) and with culm length and panicle number (r=-0.817 and -0.700 at 3.5 kg ai/ha). The differences in coefficient of culm length between herbicide rate may be attributed to the differential cultivar response (Figs. 1 and 2).

The highest path coefficients were observed with spikelet number per panicle (p=1.903 and 0.603 at 2.5 and 3.5kg ai/ha thiobencarb, respectively) and with panicle number (p=0.503 and 0.603). The path coefficients for phenotypic acceptability, culm length, and days to heading were very low indicating very low direct effects of each trait on the total number of filled spikelets. The absolute difference between the correlation coefficient and the path coefficient for these traits with total spikelets is very high (difference=0.477, 0.521, 0.634 for days to heading, culm length, and phenotypic acceptability, respectively, at 3.5 kg ai/ha thiobencarb) (Fig. 4). This result means that these traits had low direct effects on the total number of spikelets and shows the importance of path coefficient analysis. In contrast, the difference between the path coefficient and the correlation coefficients for panicle number and spikelet number per panicle was relatively low (difference=0.326 and 0.274 for panicle number and spikelet number, respectively) meaning that the indirect effects of each of the traits to total filled spikelets via the other traits is minimal.

In this study, plant height, tiller number, and

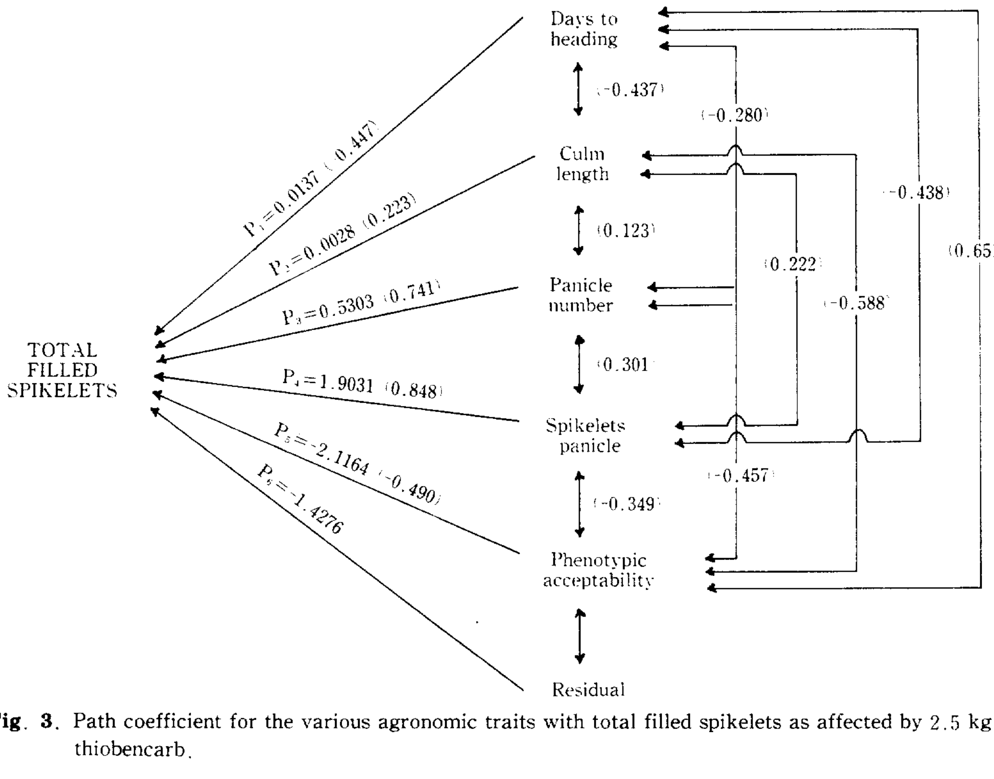

Fig. 3. Path coefficient for the various agronomic traits with total filled spikelets as affected by 2.5 kg ai/ha thiobencarb.

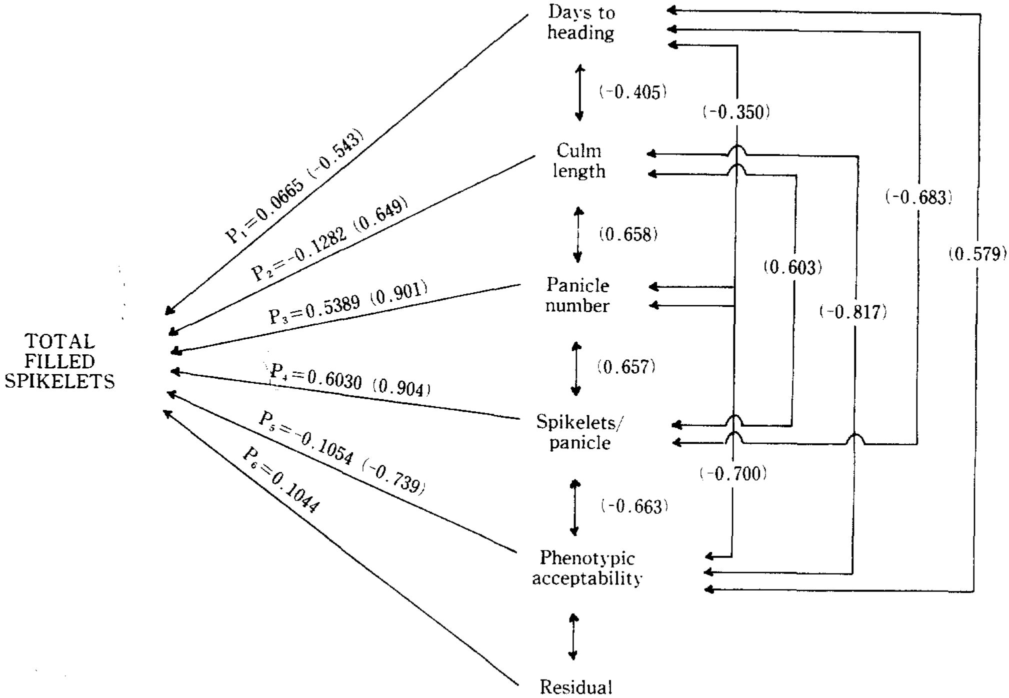

Fig. 4. Path coefficient for the various agronomic traits with total filled spikelets as affected by 3.5 kg ai/ha thiobencarb.

percent filled spikelets were not correlated with total filled spikelets although there might be a multicollinearity problem in the linear regression equation used. Further, path coefficients for phenotypic acceptability, culm length, and days to heading were very low. These results mean that these traits are not highly associated with the total number of filled spikelets. Spikelet number per panicle and panicle number which had positive significant coefficients at both concentrations are the most useful indicators of total filled spikelets. Generally, some traits in vegetative stage such as plant height and tiller number are inhibited by thiobencarb application. However, it is difficult to generalize this trend against all the varieties used or these traits are not so highly associated with the total number of filled spikelets compared to the spikelet number per panicle and panicle number.

摘 要

Thiobencarb에 대한 벼의 耐性을 豫測하는데에 여러가지 農業的 形質의 重要度를 구명키 위하여 thiobencarb에 反應을 달리하는 44品種을 對象으로 除草劑를 處理하여 諸特性을 調査하였던 結果를 要約하면 다음과 같다.

Thiobencarb 處理에 의한 草長, 分蘖數, 稈長, 이삭수, 이삭당 穎花數의 耐性 및 感受性 品種간 差異는 除草劑 處理濃度가 높을 때 더 크게 나타났으나, 出穗期, 登熟率은 除草劑 處理濃度에 影響을 받지 않았다. Thiobencarb 高濃度 處理에서 草長, 分蘖數, 登熟率을 제외한 모든 形質에 대한 回歸係數는 有意性을 보였으며 thiobencarb 濃度에 관계없이 高度의 正의 有意性을 보인 이삭당 穎花數와 이삭수가 thiobencarb에 반응을 달리한 품종들의 收量을 예측하는데 가장 有用한 要素로 나타났다.

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