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酸雨對大豆氮素累積及產量構成因素之影響

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摘要： 本試驗以pH 5.6, 4.0, 3.0和2.0之人工模擬酸雨處理大豆植株，探討酸雨對大豆各器官氮素累積及產量的影響。不同濃度酸雨噴施於大豆田間將使上層土壤(0-5公分)隨處理酸度下降，中層及下層土壤則無變化。pH 2.0將使葉片及豆莢氮素累積減少，但莖部則不受影響。由大豆植株生長介量分析結果顯示植株地上部乾重、葉面積相對生長速率、豆莢乾重相對生長速率在pH 2.0酸雨處理後降低，而產量構成因素中百粒重及每株結莢數是產量下降的原因。

關鍵語： 人工模擬酸雨、氮素累積、生長介量、土壤酸鹼度、大豆。

The effect of acid rain on the nitrogen accumulation and yield components of soybean

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Abstract. This report described the changes in nitrogen accumulation and yield of soybean plants exposed to simulated acid rain at pH 5.6, 4.0, 3.0 and 2.0 containing sulfate and nitrate (2.5:1). The pH of cultivated soil at the upper soil layer (0-5cm from surface) exposed to simulated acid rain for 5 weeks was decreased with increasing acidity of simulated acid rain. However, there was no significant difference in soil pH among any treatments for the middle and low soil layers. Leaf and pod nitrogen accumulation in plants treated with simulated acid rain at pH 2.0, were significantly low than that at pH 3.0 or higher. The analysis of growth parameters

showed that W (plant dry weight)、RGRA (relative growth rate based on leaf area) and RGRP (relative growth rate based on pod dry weight) for soybean plants at pH 2.0 during R5 stage were significantly lower than those at pH 5.6. The yield component analysis indicated that yield reduction was due to the significant reduction of 100-seed weight and number of pods per plant caused by acid rain treatment.

Key words: Simulated acid rain, Nitrogen accumulation, Growth parameter, Soil pH, Soybean.

前　　言

酸雨對作物的傷害主要在葉片，包括斑點及壞疽(necrosis)產生、表層臘質溶解、營養元素溶脫(leaching)，水份保存能力喪失，提早落葉及不正常生長和發育等(Trumble and Walker 1991)。這些因素將直接或間接影響作物最終產量。

酸雨爲害主要受處理酸度和噴施量影響，尤其是酸度高低影響雨害甚鉅，依據現有研究結果顯示，pH 3.0是傷害是否造成的關鍵酸度(Olszyk et al. 1989)。pH 4.0以上，甚少文獻指出能影響作物產量；pH 2.0以下,作物將受到嚴重傷害，至於pH 3.0的酸度則依試驗材料、處理時間、發育時期及處理時環境條件而有不同的結果。

Evans等人(1981)以pH 3.0酸雨處理大豆，發現種子產量有下降現象。Reddy (1989)以不同濃度之酸雨處理二十種大豆及十二種菜豆(snap bean)，發現pH 3.5和2.5將使產量下降。Kobayashi等人 (1991)指出pH 3.0對大豆生長過程和產量並無明顯影響，pH 2.0處理則產量明顯下降， 主要原因是葉面積伸長受阻，另由產量構成因素分析結果，每單株之種子乾重及每莢種子數顯著減少。

Evans等人(1985)以pH5.6, 4.1, 3.3及2.7處理大豆後發現種子產量隨酸度增加而依序下降，減產原因爲結莢數減少。Sinclair和de Wit (1975)指出大豆氮素需求量爲24種作物中最高者，其種子每累積1克光合產物，即需29毫克之氮素供應。而大豆全株60%以上氮素係於豆莢形成期(R4)後所累積，至於成熟期種子的含氮量可佔全株90%以上(Wang et al. 1984)，顯示大豆種子發育與充實期間，種子所需氮素的供應對產量影響極鉅。另就大豆全生育期各器官氮素的變化而言，葉片和葉柄自生育初期便逐漸累積氮素，並於R4-R5期達全生育期最大累積值，而後隨種子之發育而逐漸減少，此外，在R4-R5期時葉片亦爲各種營養要素累積最高的器官(Wang and Liu 1987)，之後隨種子充實而轉運至種子儲存。本試驗是於大豆開花後（R3期）至葉片開始黃化（R7期）處理不同酸度的酸雨，探討酸雨對大豆植株氮素累積和轉運的影響，並利用不同生長分析介量描述此段時期大豆生長及產量構成因素的變化情形。

材料與方法

本試驗於民國83年於台中縣霧峰鄉台灣省農業試驗所農場進行，以半無限型品種高雄選10號及有限型品種台農15號爲材料。田間設計採逢機完全區集設計，每區面積12m^2，行株距45×10cm。播種時每穴播3-4粒種子，於營養生長初期（V2-V3期）間拔，每穴留1株。肥料用量爲N:P_2O_5:K_2O=40:50:70 kg/ha，以基肥一次施用。定期病蟲害防治並於開花後停止使用，其他田間管理工作均按一般慣行栽培法進行。

俟大豆植株生長至盛花期後（R3期）開始酸雨噴灑，酸雨酸度爲pH 4.0, 3.0, 2.0及對照組(pH5.6)共四種處理。酸雨成份爲濃硫酸與濃硝酸以2.5:1之體積比配製成原液，再取原液滴入蒸餾水中調成固定酸度之水溶液。每次噴灑量爲1公厘雨量，每週三次，由R3期至R7期，共噴灑15次（表一）。取樣次數則依大豆生育期R3至R7期共取樣五次，每重複取五株進行生長分析，分別測定葉面積、葉乾重、莖稈乾重、豆莢重、子實重及莢數。

氮素測定是將待測樣品烘乾及秤重後，經磨粉機磨粉，將粉狀樣品置於塑膠瓶中供分析之用。全氮濃度係依本所農藝系作物生理研究室所建立之Semi-micro Kjeldahl方法測定。土壤pH值測定係依土壤與蒸餾水的比例爲1:2.5，以玻璃電極測定。大豆生育期各階段代號及其意義係依據Fehr等人(1971)之定義。

Table 1. Experimental and environmental parameters

Parameters	Spring	Summer
Simulated rain pH values	5.6, 4.0, 3.0 and 2.0	
Frequency of application	3 wk^{-1}	
Time of application	0800-0900h	
Duration of application	20min	
Simulated rain intensity	1mm	
First simulated rain	5 April	14 Sept.
Last simulated rain	10 May	19 Oct.
No. of simulated rain event	15	15
planting	27 Jan.	19 July
Harvest began	27 May	26 Oct.
Avg daily temperature (°C) during exposure period	24.9	26.9
Avg daily wind speed (m/s) during exposure period	2.5	2.4
Avg daily precipitation (mm) during exposure period	6.7	0.3
Avg daily solar radiation (MJ/m^2) during exposure period	13.4	12.9

生長分析法：

1.地上部乾重(W)=葉片乾重+莖乾重+豆莢乾重(莢果壁及種子)

2.豆莢重相對生長速率(relative growth rate based on pod weight, RGRP)

$$RGRP=\frac{\ln P1-\ln P2}{t1-t2}\times 100$$

P1:時間t1時豆莢乾重

P2:時間t2時豆莢乾重

3.葉面積相對生長速率(relative growth rate based on leaf area, RGRA)

$$RGRP=\frac{\ln A1-A2}{t2-t1}\times 100$$

A1:時間t1時之葉面積

A2:時間t2時之葉面積

4.比葉重(specific leaf weight , SLW)

SLW= LW/LA, LW:葉重(mg)，LA:葉面積(cm^2)

結果與討論

本試驗於春夏兩期作分別噴施15公厘酸雨於大豆田區，酸雨除部份沉積於葉表且造成葉部傷害外，大部份降落於地表並隨水份滲透至下層土壤。表二爲收穫期測定地表上層（0-5公分）、中層（15-20公分）及下層（25-30公分）土壤pH值變化情形，上層土壤由於酸雨的直接噴施，較易反應處理酸度的變化，即處理酸度越強，土壤pH值越低，至於中、下層土壤則無差異。

大豆根瘤固定氮素的活性以豆莢充實早期及中期達最高(Hardy et al., 1968)，所以本試驗根部測定以R5期爲準，此時酸雨量爲9公厘噴施量。根重方面，春作較夏作重，高雄選10號較台農15號重，各酸雨處理間以pH4.0較其他處理爲高（表三），此結果與Kohno和Kobayashi(1989)所作結果類似，可能原因爲pH4.0酸雨進入土壤中改變營養平衡或土壤共生細菌在土壤土層活力增強所致，但眞正原因則需進一步探討。pH3.0處理後平均根重略爲下降，但未達顯著水準。但Arnon和Johnson(1942)指出以pH3.0處理植物根部將造成傷害。

Table 2. The pH values of cultivated soil after the harvest of soybean plants exposed to simulated acid rain for 5 weeks

Crop season	Rain pH	Soil layer		
		upper	middle	lower
Spring				
	5.6	4.73a	4.99a	5.08a
	4.0	4.64a	4.65a	5.11a
	3.0	4.35ab	4.60a	4.95a
	2.0	4.19b	4.79a	5.12a
Summer				
	5.6	4.83a	4.87a	5.11a
	4.0	4.82a	5.02a	5.20a
	3.0	4.52b	4.93a	5.09a
	2.0	4.11c	4.90a	5.15a

Upper, middle and lower soil layers are 0-5, 15-20 and 25-30cm from soil surface, respectively. Means with the same letter within a column are not significantly different at 5% according to LSD test.

Table 3. Root dry weight and nodule number of soybean plants as affected by simulated acid rain

Crop season	Rain pH	Tainung 15		Kaohsiung Select 10	
		Root dry wt.	Nodule no.	Root dry wt.	Nodule no.
Spring					
	5.6	2.28b	65.25a	3.78b	65.25a
	4.0	3.02a	70.25a	4.61a	69.53a
	3.0	2.23b	69.75a	3.89b	60.57a
	2.0	1.99b	63.01a	2.51c	31.75b
Summer					
	5.6	1.30a	38.17a	2.10a	65.93a
	4.0	1.38a	37.25a	2.17a	69.14a
	3.0	1.22a	43.33a	1.89ab	58.71b
	2.0	1.08b	26.29b	1.54b	37.32c

Means with the same letter within a column are not significantly different at 5% according to LSD test.

Dustin和Raynal(1988)用糖楓(sugar maple)苗爲材料處理酸雨，也發現pH 3.0將使根毛生長受阻。但本試驗中酸雨處理後土壤剖面pH值變化，僅在上層有下降趨勢，根部根毛分佈又以土壤中、下層爲多，所以表層根毛若減少對整個根重所佔比例亦極低。至於pH2.0處理後根重則明顯下降。

根據根瘤生長的習性，根瘤菌感染根毛28-37天体積達最大，50-60天則根瘤活性開始退

化(Bergersen 1958)，而根瘤菌感染及根瘤出現比根瘤菌的生存需較高的土壤pH值(Munns, 1978)。酸雨淋洗至土壤則影響根瘤的形成(Kohno and Kobayashi 1989)。本試驗有關根瘤數方面, 雖然兩期作的施肥量皆相同，但夏作結瘤數較春作爲低，主要是夏作可利用春作殘餘氮肥，所以大豆植株本身不需過多根瘤固氮之故。在不同濃度酸雨處理間，pH 4.0之結瘤數高於其他處理，pH 3.0則和對照組相近，而pH 2.0明顯下降。大豆屬親鈣作物, 通常也需求較多鉀及鎂，並且講求鉀、鎂及鈣間的平衡(Finck 1982)。然而，高濃度氫離子將影響根部吸收陽離子，可降低鉀(Jacobson et al. 1950)、鎂、鈣、錳(Maas 1969)及鋅(Rashid et al. 1976)的含量，其中鈣離子對結瘤影響極大。Munns(1970)發現鈣離子濃度低於0.2mM及pH值低於4.8將抑制苜蓿結瘤。所以酸雨對根瘤的傷害可能與根部吸收陽離子有關，尤其是鈣離子。此外，酸性土壤將使鋁離子累積而毒害根部(Mclean 1976)，並減少根部對營養元素的吸收及轉運(Foy and Brown 1964)。至於酸雨處理大豆根部造成結瘤數的下降，是否因根部吸收陽離子受抑制，則需進一步探討。

圖一爲酸雨處理後大豆植株器官含氮量變化情形。由該圖結果可知莖部氮含量不受酸雨處理影響。台農15號葉片在pH2.0處理下，R4期即明顯下降，至R7時氮素含量祇有對照組的

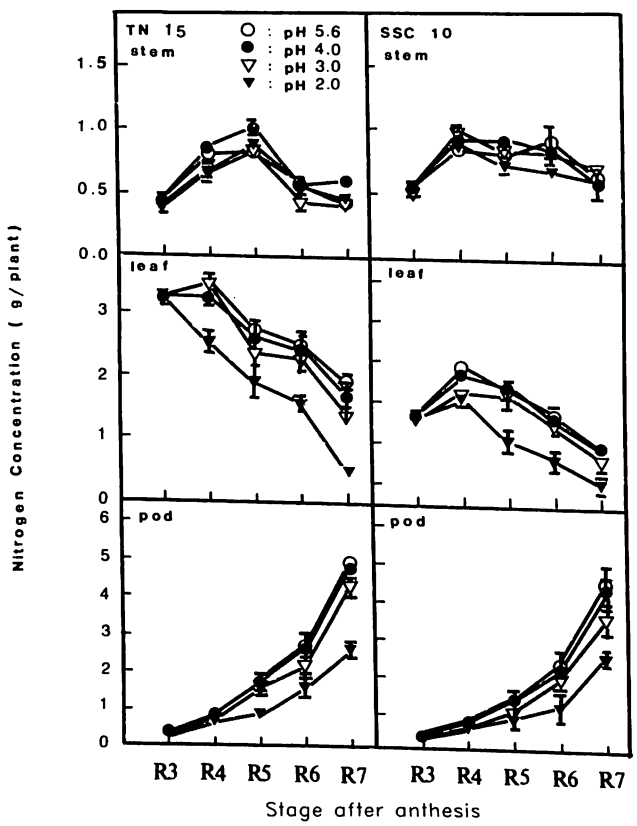


Fig. 1. Changes of nitrogen concentration in the soybean plant in simulated acid rain during reproductive growth stage of TN 15 (Tainung 15) and SSC 10 (Kaohsiung select 10) in the spring crop season. Bars indicat standard error.

一半，高雄選10號由於屬無限生長型，R4-R5期仍有新葉片長出，所以此時期氮素的下降較不明顯，pH2.0和其他處理的差異至R5期後才明顯。依據大豆生長習性，開花授粉後，豆莢長出並伸長至一定長度時才開始種子充實，此時爲R5期。種子充實期葉片爲供源(source)，將氮素及其他營養元素轉運至種子積儲，所以由豆莢氮素充實情形而言，R3-R4爲莢果壁全氮量，各處理間無差異，至R5期時pH2.0處理由於葉片含氮量明顯較低，影響豆莢氮素累積，而pH3.0亦較pH4.0及對照組爲低。

根據以往研究結果，大豆葉片在酸雨噴施二週後（約R5期），葉綠素及可溶性蛋白質開始下降，同時葉片出現斑點。由表四及表五生長分析可知，pH2.0處理後大豆植株地上部乾重(W)在R5期開始下降，至R7期祇爲對照組的一半。pH 3.0處理則在R6期有明顯下降，其中以春作台農15號較明顯，至R7期約下降15%，至於pH4.0則和對照組無差異。事實上，R5期之前地上部乾重下降主要是葉面積伸展受阻及下位葉黃化脫落所致，由葉面積相對生長速率(RGRA)可知，R5期二品種在pH 2.0酸雨處理時顯著下降。R6期時各處理之葉面積生長速率呈負值，但pH 2.0處理至R7期時下降速率反較其他處理減緩，主要原因是有新葉長

Table 4. Plant dry weight (W), specific leaf weight (SLW), relative growth rate based on leaf area (RGRA) and relative growth rate based on pod dry weight (RGRP) of soybean plants as afected by simulated acid rain in spring crop

Exposure period (stage)	Rain pH	Tainung 15				Kaohsiung Select 10			
		W	SLA	RGRA	RGRP	W	SLA	RGRA	RGRP
		g plant^{-1}	cm^{2}g^{-1}	cm^{2}cm^{-2}d^{-1}	g g^{-1}d^{-1}	g plant^{-1}	cm^{2}g^{-1}	cm^{2}cm^{2}d^{-1}	g g^{-1}d^{-1}
R3	5.6	23.1	1.2	7.6	-----	20.2	1.3	7.3	-----
R4	5.6	35.1a	2.5a	5.2a	9.6a	38.1a	2.8a	16.9a	18.6b
	4.0	33.4a	2.5a	4.6a	8.2a	34.7a	3.0a	14.6a	21.7a
	3.0	33.3a	2.6a	6.3a	8.6a	34.4a	3.1a	14.4a	18.3b
	2.0	34.9a	2.5a	6.8a	10.2a	32.5a	3.0a	15.9a	17.0b
R5	5.6	57.8a	3.0a	9.4a	12.4a	47.0a	4.3a	5.8a	24.7a
	4.0	56.5a	3.0a	10.3a	12.8a	47.9a	4.4a	6.0a	26.4a
	3.0	50.2a	2.9a	8.6a	14.3a	43.2a	4.1a	5.5a	27.8a
	2.0	40.3b	2.7b	0.8b	12.8a	33.4b	3.6b	2.4b	10.9b
R6	5.6	53.4a	3.5a	-1.2a	12.4a	80.5a	3.6a	-7.2a	10.9a
	4.0	50.2a	3.4a	-1.5a	12.1a	74.8a	3.6a	-8.4ab	8.6ab
	3.0	45.2b	3.5a	-0.7a	8.8b	67.7b	3.5a	-5.6a	6.5b
	2.0	27.3c	2.9b	-3.3b	4.9c	58.7b	3.4a	-9.6b	3.7b
R7	5.6	56.7a	2.7a	-7.8a	5.9a	102.0a	3.2a	-6.6a	6.1ab
	4.0	53.4a	2.7a	-8.7a	6.6a	97.3a	3.0a	-7.8a	7.8a
	3.0	47.3b	2.6a	-9.9a	5.2a	92.4ab	2.9a	-7.2a	5.2b
	2.0	26.7c	2.7a	-0.8b	1.3b	61.4b	2.9a	-16.0b	6.6ab

Means with the same letter within a column are not significantly different at 5% according to LSD test.

Table 5. Plant dry weight (W), specific leaf wgight (SLW), relative growth rate based on leaf area (RGRA) and relative growth rate based on pod dry weight (RGRP) of soybean plants as affected by simulated acid rain in summer crop

Exposure period (stage)	Rain pH	Tainung 15				Kaohsiung Select 10			
		W	SLA	RGRA	RGRP	W	SLA	RGRA	RGRP
		g plant^{-1}	cm^{2}g^{-1}	cm^{2}cm^{-2}d^{-1}	g g^{-1}d^{-1}	g plant^{-1}	cm^{2}g^{-1}	cm^{2}cm^{2}d^{-1}	g g^{-1}d^{-1}
R3	5.6	24.8	2.7	3.1	-----	18.4	3.2	1.8	-----
R4	5.6	42.1a	3.1a	6.6a	12.2a	38.7a	3.9a	4.2a	12.7a
	4.0	43.5a	3.2a	5.9a	13.7a	38.0a	3.8a	4.8a	11.1a
	3.0	33.5a	2.9a	6.1a	14.8a	33.5a	3.8a	5.6a	11.4a
	2.0	37.4a	3.0a	6.8a	14.9a	32.9a	3.7a	5.3a	14.7a
R5	5.6	56.4a	3.9a	12.8a	36.6a	43.5a	4.7a	13.6a	25.3a
	4.0	50.7a	4.1a	13.3a	39.7a	43.9a	4.8a	15.9a	23.2a
	3.0	53.2a	3.9a	12.9a	38.6a	38.6ab	4.6a	13.9a	29.2a
	2.0	39.6b	3.2b	8.4b	34.3a	34.5b	3.7b	8.6b	24.0b
R6	5.6	58.4a	3.5a	-1.8a	12.9a	66.9a	3.7a	-4.0a	7.6a
	4.0	58.4a	3.4a	-1.9a	10.6ab	65.2a	3.9a	-4.0a	6.2b
	3.0	58.2b	3.0a	-2.6a	10.0ab	50.9b	3.1b	-5.4a	5.0b
	2.0	53.9c	2.9b	-6.5b	7.2b	48.6b	3.1b	-7.2b	2.2c
R7	5.6	73.0a	3.1a	-16.5a	8.9a	69.6a	3.3a	-18.3a	5.1b
	4.0	69.9a	3.2a	-15.6a	7.7a	72.3a	3.2a	-16.4a	5.7a
	3.0	56.9b	3.1a	-18.3a	7.0a	64.1ab	3.2a	-17.8a	1.7b
	2.0	45.1c	2.8a	-10.4b	1.5b	51.1b	3.0a	-21.2b	1.1b

Means with the same letter within a column are not significantly different at 5% according to LSD test.

出，但此僅見於台農15號，高雄選10號則依然迅速下降。豆莢重相對生長速率(RGRP)在R5期時，除春作高雄選10號略爲下降外，其餘皆無差異，pH 2.0及pH3.0兩處理在R6期開始明顯下降，顯然種子充實受抑制。同時比葉重的變化亦可作爲解釋種子充實受抑制的原因，比葉重爲每單株葉乾重除以葉面積的比值，比值越小表示單位葉面積葉片較輕，即是葉片充實不足。因此R5期時，pH2.0及pH3.0比葉重值則較其他兩處理爲高，顯示葉片充實不足，其原因可能是葉片受傷害或根部供氮不足，無法供應葉片生長所致。至於莖部的生長速率在各處理間並無差異(資料未列)。

台灣大豆可於春、夏及秋(裏)作栽培，然因大豆對環境因子反應敏感，易受溫度、日照及其他氣象因子之影響，而導致農藝性狀及產量之差異(Wang et al. 1984, Lu et al. 1967)。根據1994年台灣省農業統計年報，民國82年全省大豆單位面積以夏作最高，春作次之，秋作最低。Breveden等人(1978)指出大豆於生殖生長早期有大量(43%-81%)落花與落莢或莢果不飽滿現象發生，因而認爲由於多數積儲同時需求大量養分（包括光合產物及營養要素），競爭的結果造成供源不足，因此Tanaka(1980)認爲供源能力爲大豆產量的主要限制因子之

Table 5. Plant dry weight (W), specific leaf wgight (SLW), relative growth rate based on leaf area (RGRA) and relative growth rate based on pod dry weight (RGRP) of soybean plants as affected by simulated acid rain in summer crop

Exposure period (stage)	Rain pH	Tainung 15				Kaohsiung Select 10			
		W	SLA	RGRA	RGRP	W	SLA	RGRA	RGRP
		g plant^{-1}	cm^{2}g^{-1}	cm^{2}cm^{-2}d^{-1}	g g^{-1}d^{-1}	g plant^{-1}	cm^{2}g^{-1}	cm^{2}cm^{2}d^{-1}	g g^{-1}d^{-1}
R3	5.6	24.8	2.7	3.1	-----	18.4	3.2	1.8	-----
R4	5.6	42.1a	3.1a	6.6a	12.2a	38.7a	3.9a	4.2a	12.7a
	4.0	43.5a	3.2a	5.9a	13.7a	38.0a	3.8a	4.8a	11.1a
	3.0	33.5a	2.9a	6.1a	14.8a	33.5a	3.8a	5.6a	11.4a
	2.0	37.4a	3.0a	6.8a	14.9a	32.9a	3.7a	5.3a	14.7a
R5	5.6	56.4a	3.9a	12.8a	36.6a	43.5a	4.7a	13.6a	25.3a
	4.0	50.7a	4.1a	13.3a	39.7a	43.9a	4.8a	15.9a	23.2a
	3.0	53.2a	3.9a	12.9a	38.6a	38.6ab	4.6a	13.9a	29.2a
	2.0	39.6b	3.2b	8.4b	34.3a	34.5b	3.7b	8.6b	24.0b
R6	5.6	58.4a	3.5a	-1.8a	12.9a	66.9a	3.7a	-4.0a	7.6a
	4.0	58.4a	3.4a	-1.9a	10.6ab	65.2a	3.9a	-4.0a	6.2b
	3.0	58.2b	3.0a	-2.6a	10.0ab	50.9b	3.1b	-5.4a	5.0b
	2.0	53.9c	2.9b	-6.5b	7.2b	48.6b	3.1b	-7.2b	2.2c
R7	5.6	73.0a	3.1a	-16.5a	8.9a	69.6a	3.3a	-18.3a	5.1b
	4.0	69.9a	3.2a	-15.6a	7.7a	72.3a	3.2a	-16.4a	5.7a
	3.0	56.9b	3.1a	-18.3a	7.0a	64.1ab	3.2a	-17.8a	1.7b
	2.0	45.1c	2.8a	-10.4b	1.5b	51.1b	3.0a	-21.2b	1.1b

Means with the same letter within a column are not significantly different at 5% according to LSD test.

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一。表六及表七爲不同濃度酸雨處理後大豆產量及產量構成因素分析表，pH2.0及pH 3.0處理後，百粒重及結莢數皆下降，pH 3.0約下降10%，pH2.0則下降40%，此結果並反應在產量上的差異，至於每莢種子數則無差異。由於本試驗酸雨處理時間爲大豆開花授粉後，所以產量高低決定於結莢數和種子充實度，酸度強的酸雨使葉片氮素累積減少及根部固氮能力下降，種子充實的供源不足而使百粒重減低，並且因供源無法提供每個豆莢結種子而脫落，造成收穫時結莢數減少。

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Table 6. Some agronomic and yield characters of soybean cultivars in spring seasons as affected by simulated acid rain

Cultivar	Rain pH	100 seeds weight (g)	Pod no.	Seed no.	Yield (kg ha^{-1})
Tainung 15	5.6	16.1a	38.0a	1.7a	1857a
	4.0	15.2a	41.5a	1.5a	1876a
	3.0	14.2a	39.1a	1.6a	1712b
	2.0	11.8b	28.5b	1.5a	1307c
Kaohsiung select 10	5.6	14.0a	72.4a	2.0a	2129a
	4.0	14.4a	69.2a	2.0a	2084a
	3.0	12.0b	68.3a	2.0a	1984a
	2.0	9.1c	56.7b	1.8b	1457b

Table 7. Some agronomic and yield characters of soybean cultivars in summer seasons as affected by simulated acid rain

Cultivar	Rain pH	100 seeds weight (g)	Pod no.	Seed no.	Yield (kg ha^{-1})
Tainung 15	5.6	13.8a	43.7a	1.9a	2006a
	4.0	13.9a	45.7a	1.9a	2120a
	3.0	12.6a	40.6a	1.8a	2050b
	2.0	9.7b	20.8b	1.8a	1518c
Kaohsiung select 10	5.6	12.9a	88.3a	2.3a	2253a
	4.0	12.5a	78.2ab	2.3a	2123a
	3.0	11.9b	77.4ab	2.3a	2097b
	2.0	10.9c	70.1b	2.2a	1693c

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