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Geometry of Lowland Rice Root System and the Relation to Above-ground Characteristics

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目的

水稻 뿌리의 分布를 模型화하므로써 몇개의 參數를 推定하여 뿌리 分布 特性을 數值化하고 그로써 地上部 特性과의 關係를 究明코자 함.

모델의 展開

* 모든 方向으로 뿌리가 均一하게 分布한다고 假定하면 (Spherical distribution)

$$N = \int_0^{\pi/2} \int_0^{2\pi} n \cos \psi \, d\psi \, d\phi = 2 \pi n \dots \dots \dots (1)$$

N : 1 株로부터 나온 全體 뿌리양, ψ : 位置角, ϕ : 方位角
n : 單位角에 나타나는 뿌리수

* 方位角에는 均一하게 分布하나 位置角에는 다르게 分布하면 (Non-spherical) 位置角에 대한 加重函數를 導入

$$g = k \exp(p, \psi) \dots \dots \dots (2)$$

k : scale factor p : Shape factor

$$n(\phi, \psi) = (N / 2 \pi) k \exp(p, \psi) \dots \dots \dots (3)$$

* (3)式을 ϕ 는 $0 \sim 2\pi$, ψ 는 $0 \sim \pi/2$ 까지 積分하면 全體 뿌리수 N이 되므로

$$k = \frac{p^2 + 1}{\exp(p \pi / 2) - p} \dots \dots \dots (4)$$

* 1 株에서 分布되는 任意의 位置(ϕ, ψ, r)에서 뿌리 密度는

$$\rho(\phi, \psi, r) = \frac{N k}{2 \pi r^2} \exp(p, \psi) \dots \dots \dots (5)$$

* $\rho_i(\phi_i, \psi_i, r_i)$ 에서 單位 體積의 뿌리 密度를 구하면

$$\rho_i(\phi_i, \psi_i, r_i) = \frac{\int_{r-\Delta r/2}^{r+\Delta r/2} N k / 2 \pi \exp(p, \psi) \, d\tau}{\int_{r-\Delta r/2}^{r+\Delta r/2} \tau^2 \, d\tau}$$

$$= (3 N k / 2 \pi) \exp(p, \psi) \frac{\Delta r}{(\tau + \Delta \tau / 2)^3 - (\tau - \Delta \tau / 2)^3} \dots \dots (6)$$

結果 要約

Table 1. 에 나타난 13개 品種에 대하여 出穗期에 뿌리 密度 分布를 個體別로 株 中心으로부터 4cm 間隔으로 調査된 結果와 (6)式을 利用하여 N 과 p의 값을 推定 하였다.

1. 單位角度로 받은 1次根의 數 n 은 方位角(ψ)와 位置角(ϕ)의 函數로 나타낼 수 있으며 $n(\psi, \phi) = (N / 2 \pi) k \exp(p, \psi)$ 로 나타낼 수 있었다.
2. 公試된 13개 品種은 1株의 全體 1次根數 N 은 674 - 1445개의 範圍 이었고 p 값은 -0.7614에서 0.095의 範圍 이었다.
3. 調査된 13개 品種의 뿌리 密度는 모델에 의해서 90% 以上說明될 수 있었다.

Table 4. Analysis of variance for the comparison of spherical model with non-spherical model. Tests were performed separately for each variety.

Variety	Source of variance	d.f	S.S	M.S	F
SR11885-201-1-3	Difference [#]	1	0.180	0.180	6.43*
	Residuals	42	1.177	0.028	
SR11349-C5-3-1	Difference	1	4.084	4.084	23.47**
	Residuals	49	8.506	0.174	
SR11349-C2-4-4	Difference	1	0.330	0.330	1.089
	Residuals	48	14.52	0.303	
Suweon330	Difference	1	2.072	2.072	37.67**
	Residuals	41	2.266	0.055	
Suweon345	Difference	1	1.380	1.380	5.638*
	Residuals	49	11.98	0.245	
Wx509 (broom)	Difference	1	0.001	0.001	0.010
	Residuals	44	4.630	0.105	
Wx509 (spread)	Difference	1	0.060	0.060	0.150
	Residuals	48	19.18	0.400	
Yongmoonbyeo	Difference	1	0.881	0.881	11.050**
	Residuals	44	0.882	0.020	
Suweon287	Difference	1	0.010	0.010	0.039
	Residuals	49	12.50	0.255	
Suweon309	Difference	1	11.004	11.004	51.181**
	Residuals	43	9.246	0.215	
V20B	Difference	1	6.132	6.132	125.14**
	Residuals	41	2.000	0.049	
V20A/Suweon287	Difference	1	5.587	5.587	39.07**
	Residuals	49	7.023	0.143	
V20A/Suweon309	Difference	1	1.440	1.440	144.00**
	Residuals	49	0.503	0.010	

difference between spherical and non-spherical models.
*,** significance at the probability level of 0.05 and 0.01, respectively.

Table 2. Results of Simplex optimization for all varieties tested.

Variety	Total root number		Shape factor		R ²	Correlation between N and p
	N	s.e. #	p	t-value		
SR11885-201-1-3	680	19.2	-0.182	2.59**	0.940	-0.399
SR11349-C5-3-1	1073	37.8	-0.349	4.33**	0.902	-0.164
SR11349-C2-4-4	1115	45.8	-0.102	0.93	0.903	-0.459
Suweon330	949	22.0	-0.365	5.84**	0.959	-0.398
Suweon345	1070	42.1	-0.210	2.11	0.920	-0.590
Wx509 (broom)	754	30.5	0.002	0.02	0.905	-0.631
Wx509 (spread)	1460	35.6	-0.020	0.38	0.957	-0.591
Yongmoonbyeo	666	13.1	-0.304	6.08**	0.961	-0.094
Suweon287	878	41.0	0.010	0.12	0.907	-0.787
Suweon309	912	22.3	-0.570	7.26**	0.940	-0.473
V20B	688	13.9	-0.525	9.55**	0.972	-0.474
V20A/Suweon287	1091	23.2	-0.340	6.02**	0.971	-0.539
V20A/Suweon309	990	27.1	-0.761	9.79**	0.942	-0.204

*,** significant difference of t-values at the probability level of 0.05 and 0.01, respectively.
sd err refers to standard error.

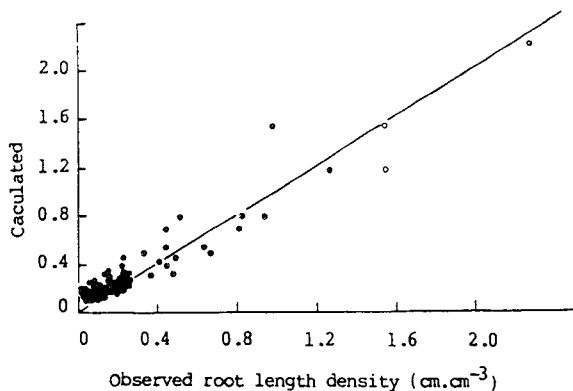


Fig. Calculated versus observed root length density for V20A/Suweon287. The solid line refers to the 1 : 1 relation.

Table 3. Calculated root distribution pattern in relation to p-value. Figures represent the percentage of roots in a given angle class.

Angle class (degree)	p-value									
	0.00	-0.15	-0.30	-0.45	-0.60	-0.75	-0.90	-1.05	-1.20	-1.35
0 - 10	17.36	18.64	19.95	21.29	22.66	24.04	25.41	26.78	28.15	29.52
10 - 20	16.84	17.61	18.36	19.09	19.79	20.46	21.13	21.80	22.47	23.14
20 - 30	15.80	16.10	16.35	16.56	16.73	16.85	16.97	17.09	17.21	17.33
30 - 40	14.28	14.17	14.03	13.84	13.62	13.37	13.12	12.87	12.62	12.37
40 - 50	12.33	11.92	11.50	11.05	10.59	10.13	9.67	9.21	8.75	8.29
50 - 60	10.00	9.42	8.85	8.29	7.74	7.21	6.67	6.13	5.59	5.05
60 - 70	7.37	6.76	6.19	5.65	5.14	4.67	4.21	3.75	3.29	2.82
70 - 80	4.51	4.04	3.60	3.21	2.84	2.52	2.20	1.88	1.56	1.24
80 - 90	1.52	1.33	1.16	1.01	0.87	0.75	0.63	0.51	0.39	0.27

Table 1. Agronomic characteristics of the varieties tested.

Variety	Heading date	Panicle number per plant	Culm length (cm)	Panicle length (cm)	Shoot W. at heading (g plant ⁻¹)	Grain yield									
							Aug. 2	Aug. 7	Aug. 11	Aug. 15	Aug. 19	Aug. 23	Aug. 27	Aug. 31	Aug. 3
SR11885-201-1-3	Aug. 2	55	64	19.4	121	12.2 h									
SR11349-C5-3-1	Aug. 7	49	72	22.2	159	14.5 h									
SR11349-C2-4-4	Aug. 3	32	70	23.2	168	15.7 h									
Suweon330	Aug. 11	47	63	23.6	172	16.5 h									
Suweon345	Aug. 17	47	61	24.8	182	17.9 h									
Wx509 (broom)	Aug. 1	50	47	25.3	198	13.1 h									
Wx509 (spread)	Aug. 1	60	46	25.8	142	17.9 h									
Suweon287	Aug. 5	47	64	25.8	175	20.7 h									
Suweon309	Aug. 3	51	62	26.2	191	19.5 h									
V20B	Aug. 5	49	56	26.8	191	19.5 h									
V20A/Suweon287	Aug. 1	62	44	27.5	215	21.7 h									
V20A/Suweon309	Aug. 2	60	59	28.1	209	23.8 h									

Grain yields followed by common letter are not significantly different at 5 % level of Duncan's Multiple Range test.

