1979

Comparison of Tolerance to High Moisture Conditions of the Soil Among Crop Plants: Studies on the Comparative Plant Nutrition [English Translation]

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Moisture tolerance in crop species – English translation

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Original reference:

Tadano, T., Kirimoto, K., Aoyama, J., and Tanaka, A. (1979). Comparison of tolerance to high moisture conditions of the soil among crop plants: Studies on the comparative plant nutrition. *Japanese Journal of Soil Science and Plant Nutrition,* 50, 261-268.

This article was discovered via a reference from Table 15 in the 1985 book 'Soil aeration and its role for plants' by Jan Gliński (see appendix), which has been cited almost 900 times.

The original reference points to the *Journal of the Science of Soil and Manure*, which was published in Japan until 1933. In 1934, the name was changed to the *Japanese Journal of Soil Science and Plant Nutrition*, and it is still published today under this name.

This article was published in Japanese in 1979 and to our knowledge has not been translated in its entirety into English. The original structure and verbiage of the article have been retained in our translation below. It includes an extensive series of studies to determine the sensitivity of crops to low oxygen and elevated CO_2 in the root-zone.

Moisture tolerance in crop species

Research on comparative plant nutrition

T. Tadano, K. Kirimoto, J. Aoyama, and Tanaka, A.

Introduction

If there is an excess amount of moisture in the soil, crops will be damaged by "moisture damage". The reasoning behind this is due to the excess amount of moisture in the soil, causing the gas exchange rate between the soil and atmosphere to decrease.

a. Decrease in O_2 concentration in soil[1]
b. Increase in CO_2 concentration in the media[2]
c. Increase in Fe concentration[3]
d. Increase in Mn concentration[4]
e. From the above mechanisms NO_2 forms

From previous studies, it has been known that different species have varying moisture resistance. Among various species, they have different factors for resistance. For example, in soybean and tobacco, if the concentration of O_2 in the medium decreases below 5%, the overall growth rate decreases. If the concentration of O_2 in tomato goes below the atmospheric O_2 concentration, then the growth rate would decrease[5]. As seen in fava bean, if the CO_2 is at 3.5%, the growth rate will hinder, stagnate, or cause growth issues[6]. In pea, common bean, and sunflowers, this would occur at 6.5% CO_2, but for oats and barley, there was no correlation between CO_2 and growth[2].

There have been several reports by previous researchers that there is an influence between high Mn concentration[7] and moisture tolerance in species. It was also reported that the Cruciferous family has a weak moisture tolerance compared to rice and corn, which have higher tolerances. There are different degrees of tolerance that plants can handle at high concentrations of Fe among species[8]. There is not a large amount of research that has been done on this, but within the few that have, it was found that wetland rice has a higher tolerance than barley, and rye has a higher tolerance than mustard and cannabis[9]. There is even less research done on different crops at the same time for researching different factors in moisture resistance/tolerance. By comparing many crops at the same time, it may be possible to find and show the order of strength of tolerance to moisture. This paper presents the order of weakness and strength of moisture tolerance of many crops. The purpose of these experiments is to analyze the different factors which may cause moisture resistance in specific plants (Table 1).

Materials and Methods

Experiment 1: Effects of aeration and no aeration in hydroponic conditions

Eighteen crops were grown between 10 - 27 days (about 4 weeks) until harvest.

Seeds were grown in quartz sand until germinated in a greenhouse and were frequently watered with fertilizer solution until ready for transplanting. The seedlings were transplanted into a tub with standard solution (56 L) (Table 2). There were 18 species, two plants of each species, for a total of 36 plants. There were four tubs and two treatment areas.

Standard section: Holes were made at both ends of the lids where rubber tubing was passed through to connect a thick glass tube with an inner diameter of 1 mm to each of the ends. Each was submerged in the standard solution, where the air was added to aerate the tub at around 700 mL per min.

Non-aerated section: The lids of the tubs were sealed with vinyl tape to prevent any air from entering. This was done in a particular ventilation area. No air was added.

Every day the pH was adjusted to about 5.5, using diluted ammonia water or HCl and H_2SO_4. During the treatment period, DI water was added to help compensate for any decrease in solution due to transpiration and evaporation.

Table 1: Species and cultivars that were used in this study and their time to harvest.

No.	Species	Scientific name	Cultivar	Family	Time (d)
1	Chrysanthemum	*Chrysanthemum coronarium* L.	Japanese	Asteraceae	22
2	Cucumber	*Cucumis sativus* L.	Japanese	Cucurbitaceae	13
3	Chili pepper	*Capsicum annum* L.	Sapporo	Solanaceae	27
4	Tomato	*Lycopersicum esculentum* Mill	Japanese	Solanaceae	16
5	Eggplant	*Solanum melongena* L.	Japanese	Solanaceae	22
6	Carrot	*Daucus carota* L.	Japanese	Apiaceae	27
7	Adzuki bean	*Phaseolus radiatus* L. var. aurea Prain	Japanese	Fabaceae	14
8	Soybean	*Glycine max* (L.) Merrill	Japanese	Fabaceae	11
9	Common bean	*Phaseolus vulgaris* L.	Japanese	Fabaceae	10
10	Pea	*Pisum sativum* D. C.	Japanese	Fabaceae	14
11	Cabbage	*Brassica oleracea* L. var. capitata L.	Golden acre	Brassicaceae	17
12	Chinese cabbage	*Brassica pekinensis* Rupr.	Japanese	Brassicaceae	14
13	Daikon	*Raphnus sativus* L. var. hortensis Backer	Japanese	Brassicaceae	14
14	Beet	*Beta vulgaris* L. var. saccharifera Alffeld	Japanese	Amaranthaceae	17
15	Onion	*Allium cepa* L.	Japanese	Amaryllidaceae	22
16	Rice	*Oryzae sativa* L.	Yukar	Poaceae	25
17	Wheat	*Triticum aestivum* L.	Haruhikari	Poaceae	14
18	Corn	*Zea mays* L.	Pioneer	Poaceae	13

Table 2: Standard solution composition.

Element	Conc. (ppm)	Compound
N	68	NH_4NO_3 (40 ppm N) $NaNO_3$ (28 ppm N)
P	10	KH_2PO_4
K	78	K_2SO_4, KCl, KH_2PO_4
Ca	80	$CaCl_2$
Mg	48	$MgSO_4$
Fe	2	$FeSO_4$
Mn	1	$MnSO_4$
B	0.5	H_3BO_3
Zn	0.2	$ZnSO_4$
Cu	0.01	$CuSO_4$
Mo	0.005	$(NH_4)_6Mo_7O_{24}$

The concentration of O_2 was measured using a Beckman-disabled oxygen analyzer. The concentration of the solution was about 21% in the standard section and about 13% in the non-aerated section (Figure 1).

The fresh weight of the plants was taken 12 days after transplanting and then dried at 75 °C. The dried weight was then measured and subtracted from the fresh weight from the time it was transplanted. The growth rates were calculated for both the aerated and non-aerated experiments.

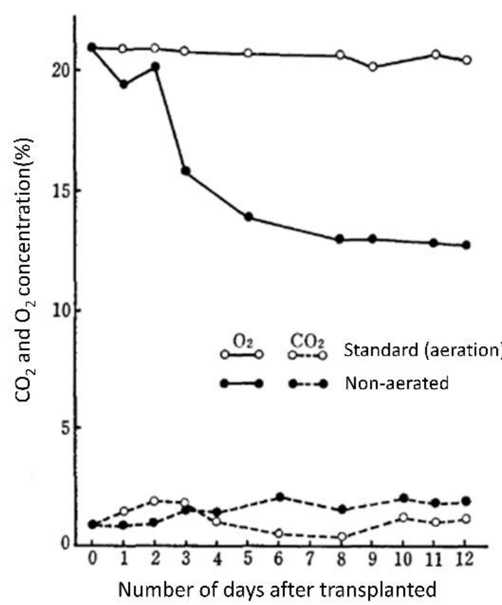

Figure 1: O_2 and CO_2 concentration over time in aerated and non-aerated conditions.

During the duration of the experiment, the CO_2 level was determined in the hydroponic solution using Conway's micro diffusion method[10]. The total carbonic acid concentration was first measured by the dispersive analysis method, and the value was then compared to the standard solution. Using these numbers, the level of CO_3 was calculated and then based on that the CO_2 level was found using Equation 1[11].

$$\log P_{CO_2} = 7.85 - pH + log\,(HCO_3{}^{-}) - 0.51\sqrt{\mu}\;(1)$$

Where μ = 16K[11]

NO gas was not detected in the non-aeration experiment.

Among species, there were different growth rates. Chinese cabbage, Chrysanthemum, and beet were 60% as large, whereas tomato, eggplant, cabbage, and wheat were 80% as large as the aerated section. The other crops were around 85% as large (Figure 2).

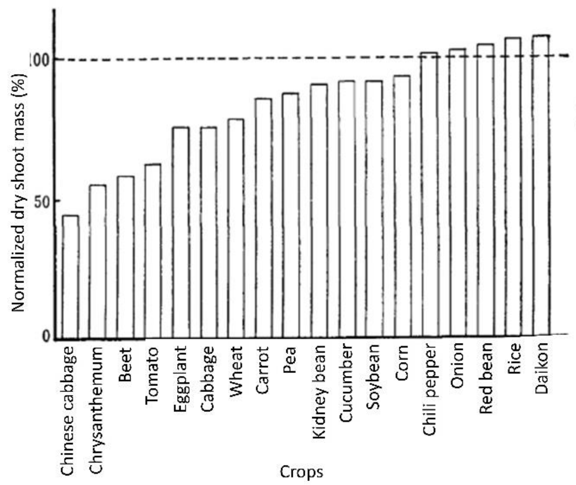

Figure 2: Normalized growth rates in non-aerated conditions.

Experiment 2: Effects of N_2 aeration in hydroponics

Like experiment 1, seedlings were transplanted to individual Erlenmeyer flasks from the same quartz sand media as previously stated, 11 replicates. Each of the crops was fixed by being held up by the neck of the flask using a rubber foam guard.

Standard section: Same as experiment 1.

N_2 aerated: A standard duplicate was created like experiment 1 but was aerated with N_2 at 200 - 300 mL per min. N_2 was aerated at the same flow rate as in the ventilated area.

The pH was adjusted daily to 5.5. Fresh weight was taken on the seventh day. The solution O_2 was kept at 21% throughout the experiment. The N_2 aerated trial reached about 2.5% in O_2 after only one day of treatment but remained constant throughout the duration of the experiment (Figure 3).

Tomato, beet, Chinese cabbage, corn, eggplant, daikon, soybean, pea, and carrot grew 51% smaller in the N_2 aerated system compared to the standard aerated system. Rice and onion grew larger in the N_2 aerated system (Figure 4).

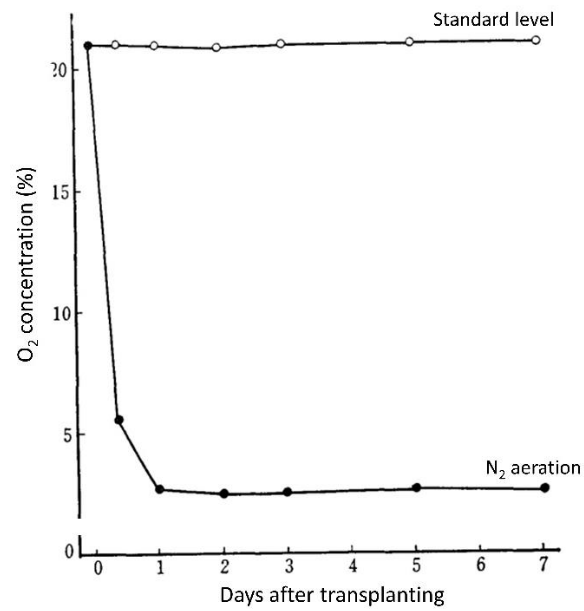

Figure 3: O_2 concentration in the culture medium during the growth period.

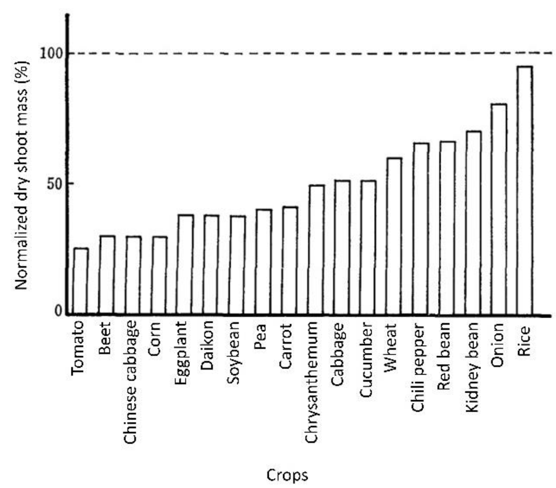

Figure 4: Normalized dry shoot mass of species in aerated conditions and with N_2 aeration in hydroponics.

The N, P, and K concentration were smaller in N_2 aerated systems compared to the standard systems. Ca and Mg were higher but still less than 100%, and Na was greater than 100% (Table 3).

Table 3: Crop species dry weight and their nutrient distribution.

All crop species average dry mass and nutrient distribution															
	Dry mass (g per plant)		Nutrient (%)												
			N		P		K		Na		Ca		Mg		
	S.L.	N_2	S.L.	N_2	S.L.	N_2	S.L.	N_2	S.L.	N_2	S.L.	N_2	S.L.	N_2
Average	0.87	0.39	5.60	3.86	0.89	0.55	5.82	3.55	0.54	0.41	1.15	0.84	0.73	0.59
SD	0.55	0.26	0.71	0.69	0.28	0.16	2.14	0.83	1.14	0.55	0.56	0.30	0.20	0.16
Comparison to S.L.*	100	51	100	68	100	64	100	64	100	144	100	79	100	82

*Average of N_2 area to standard area
S.L. = Standard levels

Experiment 3: Effects of CO_2 in hydroponic systems

Similar to experiment 1, 18 species are seeded into standardized quartz sand media. Two of each species were then transplanted into 56 L of standard solution tubs.

1. Standard section*
2. 5% CO_2
3. 3 replicates of 20% CO_2

*The standard section was the same as in experiment 1 and CO_2 was aerated respectively to the CO_2 concentrations of 5% and 20%.

The CO_2 tubes are attached to two vent tubes which were attached to a Y-shaped tube. The remaining two ends of the W-shaped tubing are connected. A vinyl ventilation system is submerged into the tub of solution where the flow rate of CO_2 is measured. CO_2 flow rate was 15 - 20 mL per min for the 5% and 60 - 80 mL per min for the 20% CO_2 tub.

Two air ventilation pipes were installed separately in the CO_2 ventilation zone. The air was ventilated at a flow rate of 150 - 200 mL per min.

The pH was checked every day and was fixed to be at 5.5.

The CO_2 concentration in the solution was extremely low, about 5.5% to 6.3%, in the 20% CO_2 treatment. It was then maintained to be at 19% to 24% CO_2 (Figure 5).

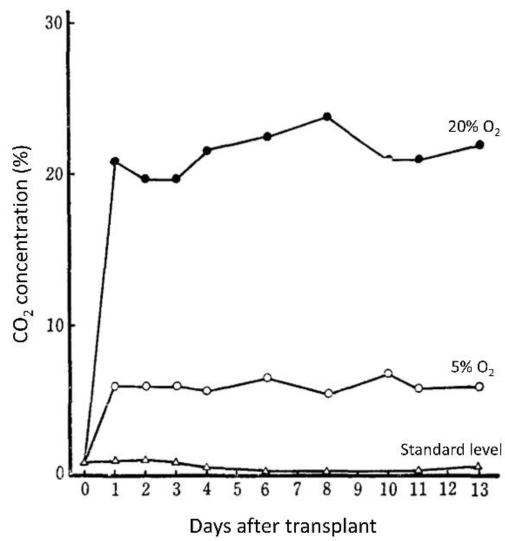

Figure 5: CO_2 concentration hydroponics over time, experiment 3

Around the fourth day after treatments began, the 20% CO_2 tub's grass family crops began to yellow on the lower leaves, and signs of root damage and stunting were observed in all crops except for onion.

After the incident, other crops in the 5% CO_2 tubs began to also yellow, except canola. The tomato, pea, pepper, etc. were stunted.

All crops were harvested on the 14th day after transplanting and the fresh weight was taken.

In the 5% CO_2, tub the growth rate relative to the control was small in cruciferous, tomato, pea, and chili pepper. In the 20% CO_2 area, 70% or more of the crop growth rates were below 70% compared to the standard, except for rice. There was a large decrease in growth and yield in cruciferous, eggplant, pea, and cucumber (Figure 6).

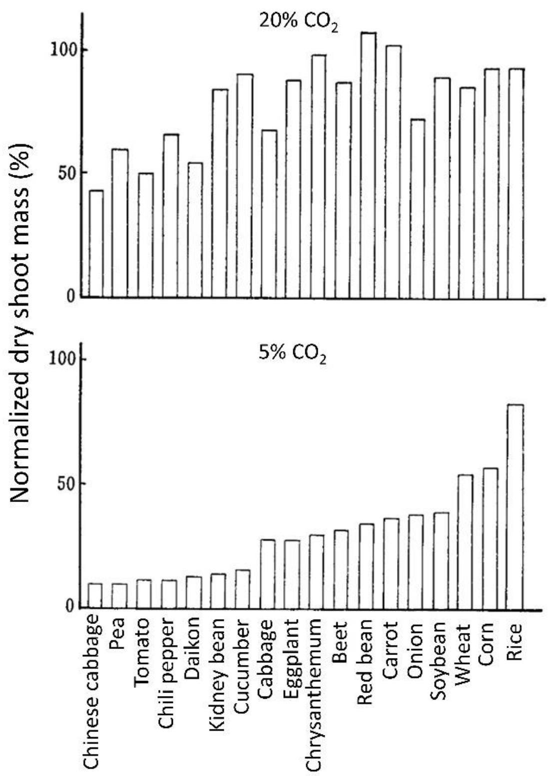

Figure 6: Normalized dry shoot mass in 5% CO_2 and 20% CO_2 sections

Experiment 4: Growth response in overly saturated media

The following treatments were set up and done at Hokkaido University in the field.

Standard field: A standard field.

Overly saturated field: Adjacent to the standard field; 25 cm of topsoil was removed to make the ground lower.

Six small plots, each sectioned out into 1 x 2 x 2.5 m plots. A 10 cm deep and 15 cm wide groove was made at each of the small plots. Tap irrigation water was gently run from the northwest side, where a small amount of water would always be flowing through the grooves of the standard area. The excess water was made to flow into the overly saturated area on the southeast side of the field.

In the overly saturated field, the height of the ditch was adjusted so that the water level in the ditch would match the ground level.

Three plants were considered one replicate (average). There were 18 species grown in advance in paper pots for 14 to 37 days. Each crop was planted in an area, with six species per plot, and was transplanted 30 cm apart from each other. This was repeated twice. The day before the plants were transplanted, the field was fertilized with 70, 70, and 50 kg/ha of N, P_2O_5, and K_2O for each of the plots.

Several times during the growing period, two spots in the plot in Ogawa[12] were sampled in the soil to a depth of 15 cm. Soil air was sampled using a capillary device and O_2 and CO_2 concentrations were measured using chromatography. The top 10 cm of the soil was sampled from each plot. The soil was then analyzed after being centrifuged to separate soil solution that was below pF of 3.8. Fe, Mn, and NO_2-N were then extracted from this sample.

After being maintained in conditions for three months, the fields were tested in 1973, transplanted on August 15th, and harvested 29 days later on September 13th. The experiment was done twice. The second trial started in June and was harvested on July 8th, 33 days after transplanting. The results were similar enough that 1973's results were omitted in this paper. (Figures 7 and 8).

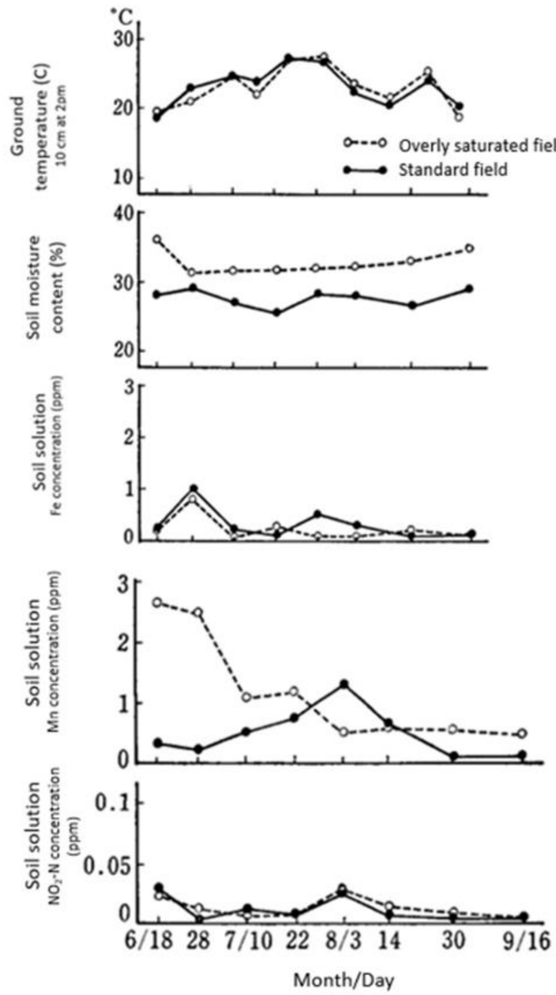

Figure 7: Soil temperature, soil moisture, and soil solution concentration of Fe, Mn, and NO_2-N during the growing season from experiment 4.

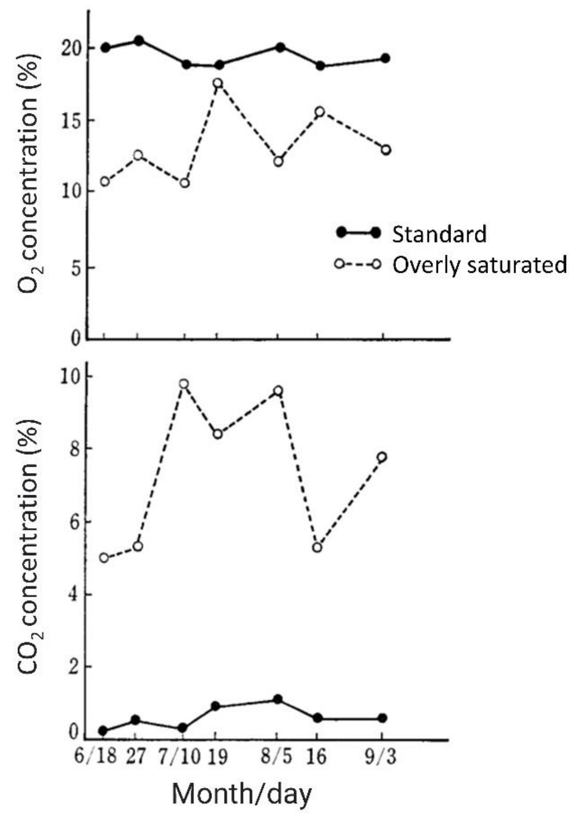

Figure 8: O_2 and CO_2 concentration in the soil during the growing season.

The soil solution was sampled and tested in 1974 to see if there was a difference between soil temperature at 10 cm between the overly saturated field and standard field.

The water and soil mixture varied from 25.5% to 28.9% in the standard field, and 31.3% to 36.1% in the overly saturated field.

The Fe concentration in both fields was below 1 ppm; there was no difference between fields.

The Mn concentration in the overly saturated field was higher compared to the standard field, but even at its highest, it was only about 2.6 ppm. When looking into the crop analysis after harvest, it showed that Mn was about twice as high in the overly saturated plot, at about 162 ppm compared to the standard plot which was about 91 ppm. This is much higher than the standard Mn found in crops.

NO_2-N for both fields was below 0.03 ppm, which was considered low. The pH for the control field was between 5.8 to 6.7 and 6.3 to 6.8 for the overly saturated field. The CO_2 concentration was 1% or lower in the standard field, and 5% to 9.8% in the overly saturated field.

The growth rate between the two fields was similar in both the 1973 and 1974 studies. The overall harvested weight in the overly saturated plot compared to the standard field in 1974 was lower. The relative growth rates in the early stages of development for all crops except rice were very different (Table 4).

Table 4. Relative growth in early development stages in standard and overly saturated fields and their dry mass of the harvested plants.

No.	Species	Time (d)*	Dry mass (g per plant)** Standard field	Overly saturated field	Index no.
1	Chrysanthemum	30	8.6	2.3	27
2	Cucumber	27	22.9	5.4	24
3	Chili pepper	26	2.95	0.15	5
4	Tomato	23	54.7	6.5	12
5	Eggplant	31	19.2	0.37	2
6	Carrot	40	10.8	1.25	12
7	Adzuki bean	45	18.3	1.78	10
8	Soybean	72	58.8	40.8	69
9	Common bean	24	9.1	0.43	5
10	Pea	34	9.7	1.57	16
11	Cabbage	13	35.5	0.40	1
12	Chinese cabbage	22	36.5	3.2	9
13	Daikon	18	9.7	0.33	3
14	Beet	27	102.3	5.7	6
15	Onion	95	5.6	1.33	24
16	Rice	103	2.8	28.8	1029
17	Wheat	46	-	-	-
18	Corn	67	179.6	100.6	56

*1973 and 1974 were both similar
**1974 harvest

Experiment 5: Groundwater level vs the distribution of roots

A root box was made with a width of 20 cm, a length of 10 cm, and a height of 30 cm. The bottom of the box was cut out with small holes that allowed water to flow in and out freely. The box was filled with 0.8 g N, 0.8 g P_2O_5, and 0.5 g K_2O added to 4 kg of Hokkaido University's soil.

The soil layer of the root box was divided into four stratigraphic layers of 0 to 2.5 cm, 2.5 to 5 cm, 5 to 10 cm, and 10 to 25 cm (Figure 9).

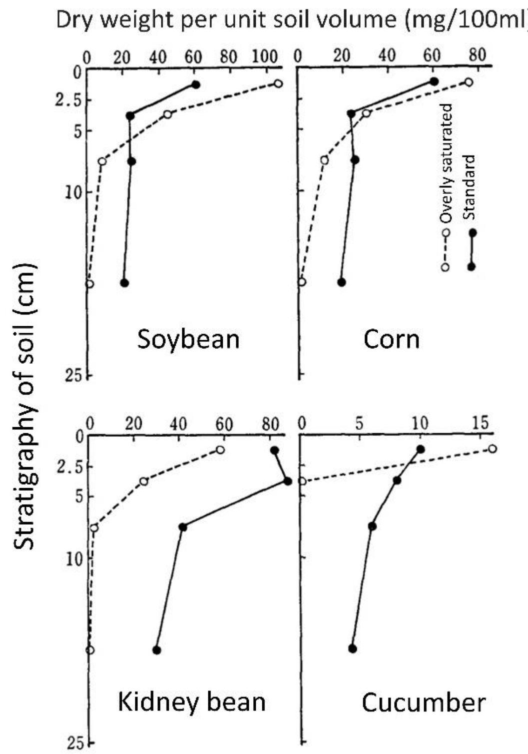

Figure 9. Root soil layers distribution per unit of soil volume (Experiment 5).

There were two replicate boxes of each, with a total of four boxes, each with two replicates of each crop. They were placed in a pad filled with water to a depth of 2 cm.

Standard section: As described above.

Overly saturated box: The root box was submerged to a depth of about 25 cm so that the water level matched the level of the soil surface of the root box.

During the experiment, 50 ppm $Ca(NO_3)_2$ was added. Occasionally 50 mL of $CaSO_4$ solution was added.

When the plant reached a height of about 5 cm, the crop was harvested. Soybean (strong moisture tolerance) was sown on August 18th and harvested on August 30th. Corn (high resistance) and cucumber (low resistance) were sown on October 21st and harvested on November 6th (Table 5).

Table 5: Dried shoot and root mass from experiment 5.

Species	Dry shoot and root mass (root box Exp. 5)					g per root box
	Shoots (Plant above surface)			Roots		
	Std.	O sat.	Index	Std.	O sat.	Index
Corn	6.3	5.3	84	1.23	0.69	56
Soybean	6.5	3.1	48	1.27	0.83	65
Cucumber	3.8	0.9	24	0.28	0.08	29
Common bean	14.4	2.0	14	2.14	0.43	20

Std. = Standard field
O sat. = saturated field

Root mass was weighed and compared per unit of soil volume of the standard and overly saturated root boxes. This showed that the stratigraphy of 0 to 5 cm section for corn and soybean in the standard plot was smaller compared to the overly saturated area. Cucumber (low moisture resistance) showed that roots were localized in 0 to 2.5 cm, which is larger than in the standard plot. Although a small number of roots were distributed in the 2 to 10 cm strata, the green bean and soybean were smaller than the standard plot in the surface area.

Discussion

Over the two years of various experiments, the average growth rate in early development in overly saturated media showed that cruciferous, solanaceous, beet, green bean, cucumber, crown daisy, pea, carrot, adzuki bean, and wheat were particularly weak, while corn, soy, and onion were strong, and rice was exceedingly considered suitable for overly saturated areas.

The early growth response was well reflected in all crops except onion.

There was no difference among species in Fe concentration in the soil solution between the overly saturated areas and the standard areas; it remained below 1 ppm through the entire trial. Therefore, it is thought that it is unlikely that this was a factor inhibiting growth in overly saturated areas.

The NO_2-N concentration was extremely low (Figure 7). According to Bingham[13] at a pH of 6.0, if the NO_2-N concentration is over 50 ppm then early signs of growth inhibition are found, especially in tomatoes and soybeans. Anything under 0.1 ppm should increase growth in plants.

The results of the hydroponic experiments show that the growth of many crops decreased in non-aerated conditions.

To analyze water resistance in low O_2 areas and high CO_2 resistance, each resistance is expressed numerically. Based on these values, the strength of resistance was judged and shown in Table 6.

1. Moisture resistance: average value of growth rate at the early stages in field tests over two years.
2. Tolerance to drought: Average growth rates between a non-aerated plot and an N_2 aerated plot in hydroponic experiments.
3. High CO_2 tolerance: average value of relative growth rate in 5% CO_2 and 20% CO_2 plots.

Table 6: Moisture tolerance, low O_2 tolerance, and high CO_2 resistance among species.

	Crop species	Low O_2 tolerance	CO_2 tolerance
Weak	Cabbage	Moderate	Weak
	Daikon	Moderate	Weak
	Chinese cabbage	Weak	Weak
	Tomato	Weak	Weak
	Common bean	Moderate	Weak
	Chili pepper	Strong	Weak
	Beet	Weak	Moderate
	Cucumber	Moderate	Weak
	Chrysanthemum	Weak	Moderate
	Eggplant	Weak	Moderate
	Pea	Moderate	Weak
Moderate	Carrot	Moderate	Moderate
	Adzuki bean	Strong	Moderate
	Wheat	Moderate	Moderate
Strong	Corn	Moderate	Moderate
	Soybean	Moderate	Moderate
	Onion	Strong	Moderate
Strongest	Rice	Strong	Strong

In Table 6, the crops are arranged in descending order of moisture tolerance from weakest to strongest. Resistance to moisture is strongest in rice, moderate in wheat, auzuki bean, and carrot, and weak in other crops.

Rice, onion, adzuki bean, and chili pepper are highly resistant to low O_2, Chinese cabbage is moderate, and tomato, beet, and chrysanthemum, are weak. Rice is highly resistant to high CO_2, and cruciferous, tomato, green bean, hot pepper, pea, and cucumber are weak.

The correlation coefficient between high CO_2 resistance and moisture resistance was significant at a 5% level even when rice was not included (Figures 10 and 11).

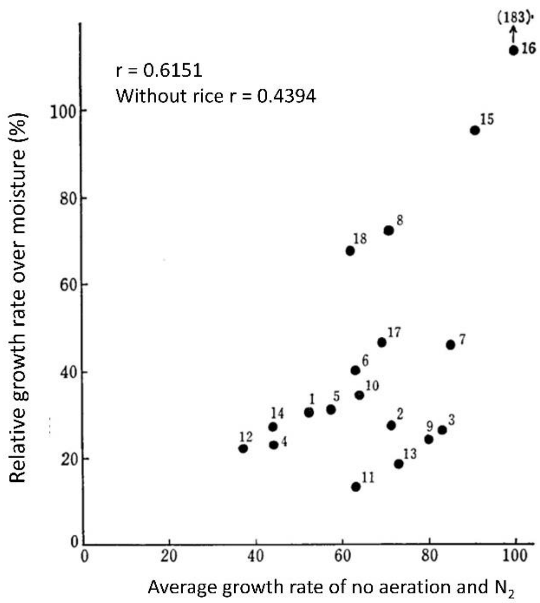

Figure 10: The average growth rate of no aeration and N_2 conditions

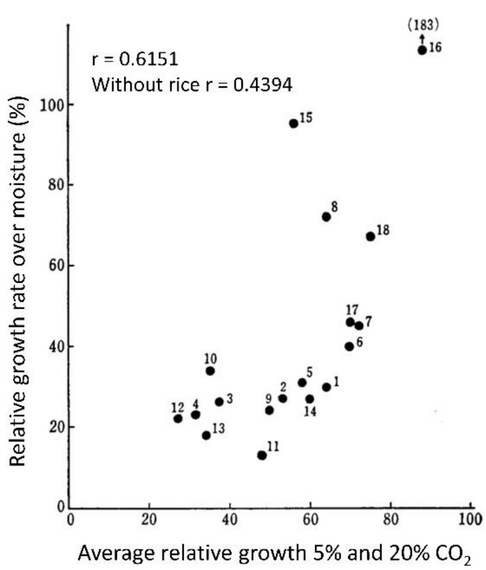

Figure 11: Average relative growth rates in 5% and 20% CO_2 conditions

Furthermore, the product of the average relative growth rate in the aerated and N_2 aerated plots and the average growth rates in the 5% and 20% CO_2 plots was significantly higher than those of the low O_2 and high CO_2 plots in the field. Considering that it reflects the degree of influence on crop growth when rice plants are removed, the correlation coefficient between this product and moisture resistance is significant at 1% even if rice plants are removed (Figure 12).

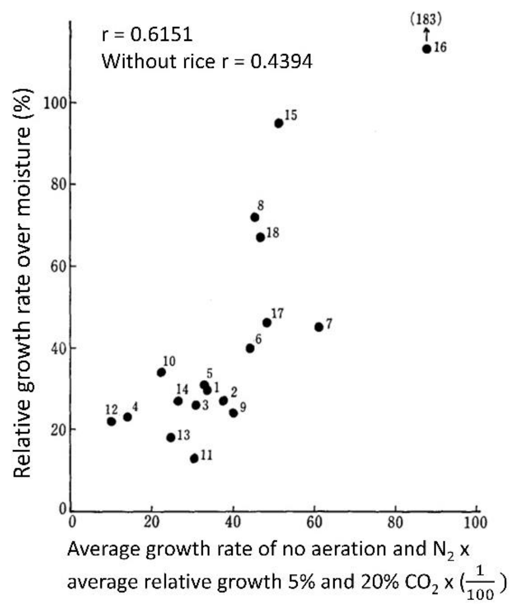

Figure 12: Relationship between factors of plants with low O_2 tolerance and high CO_2 resistance

Based on the results, the main cause of different moisture tolerance in different species is a combination of resistance of low O_2 and high CO_2.

As seen in different species, tolerance to low O_2 and high CO_2 is not the only cause of why there is variability in moisture tolerance. In addition to these factors, the characteristics of the crop's surface of the soil and how they allow the roots to grow well in overly saturated conditions are different in species.

Nutrient absorption capacity also decreases in overly saturated conditions. This was confirmed in the N_2 aeration.

However, there was no fixed relationship between the degree of decrease in nutrient content and the degree of decrease in growth rate. It has been suggested that the decrease in nutrient absorption was growth inhibition due to over-saturation, which could be a secondary rather than primary factor.

It should be noted that this experiment was conducted in the soils of Hokkaido University, where the Fe concentration and Mn in the soil solution do not increase significantly. Excess Fe and Mn may be a problem in the case of soils where the concentration of Fe and Mn in the soil increases over time under overly saturated conditions.

Conclusion

1. Resistance to high levels of moisture is particularly weak in cruciferous, solanaceous, pea, green bean, cucumber, and chrysanthemum. It is strong in corn, soybean, onion, and rice, which are usually adapted to overly saturated conditions.
2. The O_2 concentration in the air phase of the soil in the overly saturated field was as low as 10.5% to 17.5% and the CO_2 concertation as high as 5.0% to 9.8%.
3. Rice, onion, adzuki bean, and chili pepper are highly resistant to low O_2. Chinese cabbage, tomato, beet, Crown daisy, and eggplant are weak along with other crops that were studied.
4. Rice, cruciferous, tomato, Chinese cabbage, chili pepper, cucumber, and pea have a high tolerance to high amounts of CO_2.
5. Moisture resistance is a combination of the ability to resist low O_2 and high CO_2 levels
6. Some species of crops can grow on the surface of overly saturated fields if they have strong enough moisture resistance. Some even have an abundant number of roots.
7. From the research done, it can be concluded that there are many factors as to why there are different moisture resistances between species. The reasons are resistance to low O_2 and high tolerance of CO_2, and the property of extending roots to the surface of the soil when they are in overly saturated conditions.

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Appendix

Table 15 from:

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Comparison of tolerance to high moisture, carbon dioxide, and lack of oxygen in the soil among crop plants

	Crop yield under stress conditions (percent of control)				
Plant	**Flooding 12 days**	**N_2 7 days**	**5 kPa CO_2 3 days**	**20 kPa CO_2 13 days**	**Mean**
Rice	106	95	95	90	96.5
Adzuki bean	105	66	105	33	77
Onion	102	80	75	36	73
Maize	93	30	95	60	70
Wheat	77	60	85	55	69
Carrot	55	41	102	35	66
Soybean	92	37	90	37	64
Common bean	88	70	85	13	64
Cucumber	91	51	93	15	62.5
Red pepper	101	65	65	12	61
Chrysanthemum	55	49	100	28	58
Eggplant	75	37	90	27	57
Radish	107	37	55	12	53
Cabbage	75	51	52	27	51.2
Sugar beet	57	30	85	30	50.5
Peas	87	40	60	10	50
Tomato	64	25	50	12	37.7
Chinese cabbage	45	30	44	10	32.5