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THE EFFECTS OF NITROGEN RATES AND IRRIGATION LEVELS ON GROWTH, YIELD AND NUTRIENT CONTENTS OF CABBAGE (*Brassica oleracea* L. var. Capitata)

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SUMMARY : *Cabbage plants (Brassica oleracea L. var Capitata cv. Zohrap) were grown in field conditions to determine the effects of nitrogen concentration and irrigation levels on plant growth, the number and weight of non wrapper leaves; percentage of heading; diameter, height and weight of head, and yield. Number and weight of non wrapper leaves significantly increased with increasing nitrogen concentration. On the other hand, the lowest irrigation level increased the number of non wrapper leaves whereas the highest irrigation level decreased. The percentage of heading, diameter and weight of heads were greatest when 20 kg N/da applied at 20 % irrigation level. In general, the height of head statisticaly increased with increasing nitrogen application at all irrigation levels. But it decreased when more than 20 kg N/da applied at 20 and 60 % of irrigation levels. The marketable yield increased with increasing N concentrations up to 20 kg N/da at those plots which were irrigated when 20 and 40 % of available water used; or up to 15 kg N/da at plots watered 60 % of irrigation level. More than 15 or 20 kg, N/da applications depends on irrigation levels, decreased marketable yield. The greatetst N content occured at the plots which were applied 25 kg N/da and irrigated when 20 % of available water used. It means N content of leaves increased with increasing N concentration and irrigation level. Increasing nitrogen concentration up to 20 kg N/da and at 20 % irrigation level increased P content of leaves whereas decreasing irrigation level and more than 20 kg N/da applications decreased. In general K content of cabbage leaves increased linearly with increasing N opplication rate. But more than 20 kg N application rate at 20 and 40 %, and 15 kg N/da at 60 % irrigation level decreased K accumulation in the leaves. Accumulation of Ca in the leaves was increased linearly with increasing nitrogen concentration and irrigation levels. The highest Ca content of leaves occured at 25 kg N/da application with 20 % irrigation level.*

FARKLI AZOT DOZLARI İLE SULAMA SEVİYELERİNİN LAHANA (*Brassica oleracea* L. var. Capitata)'DA BİTKİ GELİŞMESİNE, VERİME VE BAZI BİTKİ BESİN ELEMENTLERİ İÇERİĞİNE ETKİSİ

ÖZET : *Bu araştırma, Erzurum ekolojik koşullarında yetiştirilen lahana (Brassica oleracea L. var. Capitata)'da farklı azot dozları ile sulama seviyelerinin bitki gelişimi, açık yaprak sayısı ve ağırlığı,*

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baş tutma oranı, baş çapı, baş yüksekliği ve baş ağırlığı ile verime etkisini belirlemek amacıyla yapılmıştır. Denemede dekara 0, 5, 10, 15, 20 ve 25 kg'lık azot dozları ile topraktaki kullanılabilir suyun % 20, % 40 ve % 60 azaldığında toprağı tekrar tarla kapasitesine getirecek miktarda su uygulamaları üzerinde durulmuştur. Araştırma sonunda azot dozunun artmasıyla açık yaprak sayısı ve ağırlığının arttığı belirlenmiştir. Bunun yanında açık yaprak ağırlığı, kullanılabilir su % 20 azaldığında yapılan sulamada en az olmuştur. Baş tutma oranı, baş çapı ve ağırlığı dekara 20 kg azot uygulamasında ve topraktaki kullanılabilir su % 20 azaldığında yapılan sulamada en yüksek olmuştur. Genellikle baş yüksekliği bütün sulama seviyelerinde azot dozunun artmasıyla istatistiki anlamda artmıştır. Fakat kullanılabilir su % 20 ve % 60 azaldığında yapılan sulamada ve dekara 20 kg'dan fazla azot uygulandığında baş yüksekliği azalmıştır. Pazarlanabilir ürün miktarının kullanılabilir su % 20 ve % 40 azaldığında yapılan sulamada dekara 20 kg azot uygulamasına kadar artarak dekara 25 kg N uygulamasında azaldığı belirlenmiştir. Fakat kullanılabilir su % 60 azaldığında dekara 15 kg N uygulamasına kadar artmış, daha yüksek azot dozlarında azalmıştır. Bitkide en yüksek N içeriği kullanılabilir Su % 20 azaldığında yapılan sulamada ve dekara 25 kg N uygulamasında meydana gelmiş olup, yapraklardaki N içeriği sulama sıklığı ve azot konsantrasyonunun artışı ile artmıştır. Yapraktaki P içeriği dekara 20 kg azot uygulamasına kadar artmış, daha yüksek azot dozlarında azalmıştır. Fakat sulama sıklığının azalması yapraktaki P içeriğinin azalmasına neden olmuştur. Genel olarak yapraktaki K içeriği azot uygulamasının artmasıyla doğru orantılı olarak artmış, fakat % 20'lik sulama seviyesinde dekara 20 kg, % 60 su seviyesinde dekara 15 kg azot uygulamasından daha yüksek dozlarda azalmıştır. % 40'lık sulama seviyesinde ise dekara 20 ve 25 kg N uygulandığında K seviyesi aynı kalmıştır. Yapraklardaki Ca miktarı % 20 ve % 40'lık sulama seviyelerinde azot dozlarının artmasıyla artmıştır. Fakat % 60'lık sulama seviyesinde dekara 25 kg N uygulamasında azalmıştır. En yüksek Ca içeriği dekara 25 kg azot ve kullanılabilir su % 20 azaldığında yapılan sulamada meydana gelmiştir.

INTRODUCTION

Nitrogen fertilization for vegetable crops should supplement the nitrogen that becames available in the soil during the growing season in order to provide optimum yield and quality the portions of the plants used for human consumption. Uptake of N by crops and loss on N from residual soil and fertilizer N are affected by soil conditions especially water, temperature (Bandel et al., 1980), and soil pH (Smith and Chalk, 1980). Irrigation, howewer, an important management factor affecting the N fertilization program (Thomas et al., 1970).

MATERIAL AND METHODS

This study was carried out on the irrigated area no 6 of Agricultural Research and Extension Center, College of Agriculture, University of Atatürk, Turkey in 1987-1988. The classification of soil was loamy. The seeds were sown on 1st April and

seedlings were transplanted on 20 th and 15 th May, in 1987 and 1988, respectively. The plants were grown 75 cm apart within-row spacing 75 cm in plots of 6 to 4.5 m. Everyplots consisted of 48 plants. The experiment was terminated on 22 nd, October in both years. A 3x5 factorial design with 4 replications was used. There were 3 irrigations and 5 N treatments. Nitrogen as ammonium nitrate was applied at rates 0, 5, 10, 15, 20 and 25 kg per decar (Hawort, 1962; Antoniani, 1974; Hellwig et al, 1977; Kolota, 1982; Dragland, 1984). 5 kg N, 12 kg P_2O_5 and 10 kg K_2O per decar were applied to all plots except control plots before planting. The remainder of the N was applied in 20 days internals as 5 kg N/da (Akratanakul et al., 1977; Dragland, 1982).

The 3 irrigation treatments were irrigate when the avarage soil water suction of the surface 40 cm of the soil approached 0.8, 1.6 and 3.6 bars, respectively (Thomas et al., 1970; Gancharyk and Paulenka, 1975; Tyurina, 1975). This corresponds to avarage water contents of 60, 40 and 20 % available water.

Soil moisture was monitered gravimetrically (Chaudhry and Erinne, 1984). Soil samples were collected down to 40 cm depth just before and 48 hours after each irrigation (Hegde, 1987).

When experiment was terminated, 7th, 8th, 9th, and 10th non wrapper leaves (Dean and Herron, 1981; Hara et al., 1982) were taken at random from each plot. Samples were dried at 65 C^o, ground and analyzed for N by Kjeldahl; P by colorimetre, K by flame fotometre and Ca by atomic absorption spectrophotometre.

RESULTS AND DISCUSSION

Non wrapper leaves

Nitrogen applications and irrigation levels affected significantly number and weight of non wrapper leaves (Table 1). Number and weight of non wrapper leaves steadily increased with increasing N concentration at all irrigation levels. The highest number and weight of non wrapper leaves occured with 25 kg N application per decar at I-3 and I-2 irrigation treatments, respectively. This reflects that nitrogen application with adequate water supply decreased both number and weight of non wrapper leaves. In general, 10 or more than 10 kg N applications per decare significantly increased the number of non wrapper leaves in comparison to control at all irrigation levels. It means larger and faster rate of development of plants related to N application.

I-1 irrigation treatment had significantly higher number of non wrapper leaves than 1-2 and I-3 treatments whereas there was no significant diference between I-2 and I-3 irrigation treatments (Table 1). On the other hand the effect of irrigation treatments on weight of non wrapper leaves were significantly different and it was highest and lowest at I-1 and I-2 irrigation treatments, respectively. Similar results were obtained from

Table 1. Effect of N Rates and Irrigation Regimes on Number and Weight of Non Wrapper Leaves, Percentage of Heading; Diameter, Height and Weight of Heads, and Yield of Cabbage

Nitrogen applied	Irrigation regime			Nitrogen mean
	I-1	I-2	I-3	
kg/da	Number of non wrapper leaves (No/plant)			
0	16.24 d	16.53 d	18.15 c	16.97 e
5	16.74 cd	17.74 cd	19.24 bc	17.90 de
10	18.15 bcd	19.81 bc	20.30 abc	19.42 cd
15	19.28 abc	21.15 ab	21.62 ab	20.68 bc
20	20.68 ab	21.87 ab	22.56 ab	21.70 ab
25	21.62 a	22.77 a	23.24 a	22.54 a
İrrigation mean	18.78 B	19.98 A	20.85 A	
Weight of non wrapper leaves (g/plant)				
0	2336 c	2510 d	2546 c	2464 c
5	2406 c	2755 cd	2770 bc	2644 c
10	2738 bc	3052 bc	2855 bc	2881 b
15	3109 ab	3330 ab	3181 ab	3206 a
20	3222 a	3460 ab	3313 a	3331 a
25	3288 a	3573 a	3322 a	3394 a
İrrigation mean	2850 C	3113 A	2998 B	
Percentage of heading (%)				
0	94.53 b	91.27 c	89.05 c	91.61 c
5	96.61 a	96.09 b	92.70 b	95.13 b
10	97.65 a	97.39 ab	95.83 a	96.95 a
15	97.65 a	97.91 a	95.30 a	96.95 a
20	97.91 a	97.13 ab	94.52 a	96.52 a
25	96.35 a	96.87 ab	92.96 b	95.39 b
İrrigation mean	96.78 A	96.11 A	93.39 B	
Diameter of heads (cm)				
0	21.40 e	20.05 d	16.96 c	19.47 e
5	25.07 d	22.48 d	19.53 c	22.36 d
10	31.57 c	26.43 c	25.57 b	27.85 c
15	38.59 b	32.22 b	29.44 a	33.41 b
20	44.67 a	38.71 a	30.90 a	38.09 a
25	44.36 a	39.92 a	31.70 a	38.67 a
İrrigation mean	34.27 A	29.96 B	25.69 C	
Height of heads (cm)				
0	18.25 b	17.07 c	17.58 b	17.63 d
5	19.94 a	18.33 bc	17.91 ab	18.72 c
10	20.20 a	18.37 ab	18.43 ab	19.00 bc
15	20.51 a	19.66 ab	19.44 a	19.87 ab
20	21.54 a	20.11 a	19.63 a	20.42 a
25	20.22 a	20.24 a	18.67 ab	19.71 ab
İrrigation mean	20.11 A	18.96 B	18.61 B	
	Weight of heads (g)			
0	4355 d	3884 e	3469 e	3902 e
5	5661 c	4905 d	4298 d	4954 d
10	6590 b	5390 c	4780 c	5586 c
15	7217 a	6191 b	5721 a	6376 b
20	7789 a	6788 a	5604 ab	6727 a
25	7354 a	6660 ab	5224 bc	6412 b
İrrigation mean	6494 A	5636 B	4849 C	
Yield (kg/plot)				
0	197.5 e	170.5 e	148.1 e	172.0 e
5	262.5 d	226.2 d	191.3 d	226.6 d

previous studies (Rahmen et al., 1984; Shu, 1984; Fischer and Nel, 1985; Guillard and Allinson, 1988).

Heading

Nitrogen application significantly increased percentage of heeding (Table 1). But effect of nitrogen application depends on irrigation regime. Application of nitrogen up to 20, 15 and 10 kg N per decar increased percent of heading at I-1, I-2 and I-3 irrigation treatments, respectively. As mean of nitrogen applications, the lowest percent of heading occured at no nitrogen applied plots whereas the highest percent of heading at nitrogen applied plots from 10 to 20 kg per decar. On the other hand as mean of irrigation treatments, there was no significant difference between I-1 and I-2 irrigation regime on heading whereas I-3 irrigation treatment had significantly lower than others. Frequent irrigation (Ware and McCollum, 1975) and nitrogen application (Vittum, 1950) increased percent of heading in cabbage growing. The results obtained in this study support these reports.

Heads

Diameter of heads steadily increased with increasing nitrogen rates in all irrigation regimes except 25 kg N per decar at I-1 irrigation treatment (Table 1). Also frequent irrigation significantly increased diameter of head and it was 34.27, 29.96 and 25.69 cm at I-1, I-2 and I-3 irrigation treatments, respectively. The influence of irrigation treatments on hight of heads were significant and it was highest at I-1 irrigation treatment. On the other hand, more than 20 kg N per decar generally decreased hight of heads, but it was not statistically significant.

Irrigation and aplication of N fertilizer significanly increased weight of heads. The head weight increased up to 20 kg N per decar at I-1 and I-2 irrigation treatments whereas 15 kg N per decar at I-3 irrigation regime. It means more irrigation level needed to maintain the cabbage plants growing when nitrogen rates increased. As mean of nitrogen application, more than 20 kg N decreased head weight since the available water was inadequate in the soil. Heads weighted 6494, 5636 and 4849 g at the I-1, I-2 and I-3 irrigation treatments, respectively.

Yield

Both of nitrogen application and irrigation significantly increased yield (Table 1). Application of nitrogen up to 20 kg per decar steadily increased the cabbage yields at I-1 and I-2 irrigation levels whereas up to 15 kg N per decar at I-3 more than 20 or 15 kg N per decar, depends on irrigation treatments decreased yield. A significant nitrogen-irrigation treatment interaction reflected the lach of response to nitrogen by the

cabbage yield under inadequate irrigation treatments. At the I-1 irrigation treatment yield increased from 197.5 kg per plot with no application of nitrogen to 262.5, 308.7, 338.3, 365.8, 340.1 and 302.1 kg per decar with the application of 5, 10, 15, 20 and 25 kg N per decar respectively. More than 20 kg N per decar at this irrigation regime decreased the yield. On the other hand at the I-3 irrigation regime yield increased from 148.1 kg per plot to 191.3, 219.6, 261.6, 254.3 and 234.2 kg per plot with the application of 0, 5, 10, 15, 20 and 25 kg N per decar respectively. The yield decreased with more than 15 kg N application. Yield, as mean of irrigations obtained 302.1, 260.9 and 218.2 kg per plot at I-1, I-2 and I-3 irrigation treatments, respectively. The effect of irrigation regimes on the yield were statistically significant. The response of cabbage plants to the N in the I-1 irrigation treatment was higher than I-2 and I-3 irrigation treatments since the available water in the soil was high. The results obtained in this study reflect that more irrigations needed to maintain the soil water within the desired ranges was affecterd by the application of nitrogen. Similar results obtained by Thomas et al., (1970), Mangal et al., (1981), Rahman et al., (1984).

N content

N content of cabbage plants was influenced by N rates used at all irrigation levels (Table 2). N content steadily increased at I-1 and I-2 irrigation regimes whereas it decreased when more than 20 kg N decar applied at I-3 treatment. As mean of nitrogen application nitrogen rates statistically increased N content of plants. On the other hand N content of cabbage was increased by frequent or high level irrigation. The highest content of N in leaves occured when irrigation was I-1 level whereas it was lowest at I-3 irrigation treatment.

P content

P content of plants increased with increasing N rates up to 20 kg N per decar at all irrigation regimes except I-2 (Table 2). In general the effect of N rates on P content was statistically significant but the difference between 20 and 25 kg N per decar was not P content of cabbage was also influenced by irrigation regimes. It was highest and lowest at I-1 and I-3 irrigation treatments, respectively. The differences between irrigation levels were statistically significant.

K content

The K level in leaves of cabbage increased with increasing N rates up to 20 and 15 kg N per decar at I-1 and I-2 and I-3 irrigation regimes, respectively (Table 2). Irrigation regimes affected K content. As mean of irrigation levels K content increased

with increasing irrigation level and at I-1 irrigation treatment. K concentration was higher than other irrigation treatments.

Ca content

Ca concentration was influenced by N rates and irrigation regimes Ca content of leaves steadily increased with increasing N rates at all irrigation regimes with exception I-3 treatment (Table 2). It was decreased when more than 20 kg N per decar used. Ca concentration in leaves of cabbage was highest and lowest at I-1 and I-3 irrigation regimes, respectively.

Table 2. Influence of N Rates and Irrigation Regimes on Nutrient Content

N content (%)				
0	1.73 f[z]	1.69 f	1.52 d	1.64 e
5	1.82 e	1.80 e	1.72 c	1.78 d
10	2.06 d	1.91 d	1.82 b	1.92 c
15	2.43 c	2.03 c	1.90 a	2.12 b
20	2.66 b	2.15 b	1.91 a	2.24 a
25	2.75 a	2.23 a	1.79 b	2.25 a
İrrigation mean	2.27 A	1.97 B	1.77 C	
P content (%)				
0	0.210 e	0.200 e	0.170 d	0.193 e
5	0.240 d	0.215 cd	0.215 c	0.223 d
10	0.270 c	0.225 c	0.235 b	0.243 c
15	0.295 b	0.255 b	0.265 a	0.271 b
20	0.320 a	0.285 a	0.265 a	0.290 a
25	0.310 ab	0.290 a	0.255 a	0.285 a
İrrigation mean	0.274 A	0.245 B	0.234 C	
K content (%)				
0	2.55 d	2.51 e	2.50 c	2.52 e
5	2.66 c	2.61 d	2.54 bc	2.60 d
10	2.75 c	2.71 c	2.59 abc	2.68 c
15	3.16 b	2.87 b	2.65 a	2.89 b
20	3.54 a	3.07 a	2.64 ab	3.08 a
25	3.53 a	3.07 a	2.60 ab	3.06 a
İrrigation mean	3.03 A	2.80 B	2.58 C	
Ca content (%)				
0	0.450 e	0.430 d	0.385 d	0.420 f
5	0.515 d	0.455 d	0.440 c	0.470 e
10	0.545 c	0.510 c	0.480 b	0.511 d
15	0.650 b	0.550 b	0.515 a	0.571 c
20	0.750 a	0.675 a	0.515 a	0.646 a
25	0.765 a	0.680 a	0.480 b	0.641 b
İrrigation mean	0.612 A	0.550 B	0.469 C	

z mean seperation within columns by Duncans multiple range test at $P<0.05$.

In general there was a trent for higher N rates up to 20 kg N per decar and for higher irrigation level to increase N, P, K and Ca concentrations in leaves of cabbage. These results obtained in this study are in agreement with the findings of other

investigators (Wiebe et al., 1977; Dean and Herron, 1981; Peck, 1981; Smirnov et al., 1982; Geissler and Henkel, 1985; Welch et al., 1985; Wiedenfeld, 1986; Bomme et al., 1987; Guillard and Allinson, 1988; Kuchenbuch et al., 1986). Consistent decreases in concentrations of nutrient elements in leaves from low irrigation level, in comparison to those from high irrigation level, suggest that these plants may have been under water stress. Increasing N rates needed to increase irrigation level to be used more effectively. There were no significant nitrogen x irrigation interactions affecting leaf nutrient concentrations.

REFERENCES

Akratanakul, W., J.R. Baggett, H.J. Mack, 1977. Effect of plant spacing, fertilizer, and transplanting on axillary heading in cabbage, *Brassica oleracea* L. (Capitata group). Hort. Sci., 12: 56-57.

Antoniani, C., 1974. A fertilizer trial with hearting cabbage. Horti. Abst., 45, No: 3164.

Bandel, V.A., S. Dzienia, G. Stanford, 1980. Comparison of N fertilizers for no-till corn. Agron. J., 72 : 337-341.

Bomme, U., K. Eid, A. Kraus, 1987. Stickstoffdüngung bei weisskohl für die sauerkrautherstellung gemüse, 23: 62-64.

Chaudhry, A.B., E.C. Erinne, 1984. Determination of optimum irrigation frequency for onion in the kainji lake region of nigerian savanna. Gartenbauwissenchaft, 49 : 117-121.

Dean, E.K., J.W.Herron, 1981. Influence of tillage system, plant spacing, and nitrogen on head weight, yield, and nutrient concentration of spring cabbage. J. of the American Society for Hort. Sci., 106: 540-545.

Dragland, S., 1982. Timing of nitrogen application to white cabbage. Hort. Abst., 53 : 3289.

Dragland, S., 1984. Rates and timing of nitrogen application to late cabbage. Hort. Abst., 55 : 1406.

Fischer, H.H., P.C. Nel, 1985. The effect of soil moisture conditions on certain plant characteristics of head cabbage (*Brassica oleracea* var. Capitata). Proceedings of the Fifteenth Annual Congress of the South African Society of Crop Production, 39-49.

Gancharyk, M.M., Z.R. Paulenka, 1975. The effect of varying water supply on the water regime and productivity of head cabbage. Hort. Abst., 47 : 415.

Geissler, T., A. Henkel, 1985. Beziehungen zwischen Beregnung und nahrstoffversorgung bei der gemüseproduktion im Freiland. Gartenbau, 32: 165-166.

Guillard, K., D.W. Allinson, 1988. Effects of nitrogen fertilization on a chine cabbage hybrid. Agronmy Journal, 80: 21-26.

Hara, T., A. Nekegawa, Y. Sonoda, 1982. Effect of nitrogen supply and removal of outer leaves on the head development of cabbage plants. Hort. Abst., 55 : 959.

Haworth, F., 1962. The effects of different rates of application of nitrogenous fertilizer on the yield and mineral composition of spring cabbage. J. Hort. Sci., 37: 35-43.

Hegde, D.M., 1987. Effect of soil moisture and N fertilization on grown, N uptake, and water use bell pepper (*Capsicum annum* L.) Gartenbauwissenchaft, 52: 180-185.

Hellwig, A., M. Osinka, R. Mutor, 1977. The effect of irrigation and increasing nitrogen rates on the productivity of early cabbage and cauliflower. Hort. Abst., 48 : 1372.

Kolota, 1982. Effect of nitrogen fertilization and irrigation on cropping in cabbages and leeks. Hort. Abst., 53: 6465.

Kuchhenbuch, R., N. Claassen, A. Jungk, 1986. Potassium availability in relation to soil moisture. Plant and Soil. 95: 221-231.

Mangal, J.L., M.L. Pandita, B.R. Batra, 1982. Effect of irrigation intensities and nitrogen levels on growth and yield of cabbage (*Brassica oleracea* var. Capitata) variety golden acre. Haryana J. Hort. Sci., 11: 92-96.

Peck, N.H., 1981. Cabbage plant responses to nitrogen fertilization. Agron. J., 73: 679-684.

Rahman, M.A., M.M. Rashid, Z.Karim, 1984. Response of cabbage to water use efficiency at different levels of nitrogen in the grey terrace soil. Bangladesh J. of Agricultural Research, 9: 19-26.

Shu, H.L., 1984. Factors affecting the leaf growth and leaf head formation of chinese cabbage. Gartenbauwissenschaft, 49: 112-116.

Smirnov, P.M., S.D. Bazilevich, L.V. Obukhovskaya, 1982. Effect of nitrogen fertilizer and N-serve on the accumulation of nitrates in vegetable crops. Hort. Abst., 52: 5405.

Smith, C.J., P.M. Chalk, 1980. Gaseous nitrogen evaluation during nitrification of ammonia fertilizer and nitrate transformation in soils. Soil. Sci. Society of American J. 44: 277-281.

Thomas, J.R., L.N. Namken, R.G. Brown, 1970. Yield of cabbage in relation to nitrogen and water supply. American Society For Hort. Sci., 95: 732-735.

Tyurina, S.M., 1975. The effect of irrigation on some physiological process in head cabbage. Hort. Abst., 47 : 416.

Vittum, M.T., 1950. Effect of soil fertility level on the performance of eight strains of danish ballhead cabbage. Proceedings of the American Society For Hort. Sci. 56: 257-260.

Ware, G.W., J.P. McCollum, 1975. Producing Vegetable Crops. The Interstate Printers and Publisher, Illinois.

Welch, N.C., K.B. Tyler, D. Ririe, 1987. Cabbage yield and nutrient uptake. California Agriculture, 39: 30-31.

Wiebe, H.J., H.P. Schatzler, W.Kühn, 1977. On the movement and distribition of calcium in white cabbage in dependence of the water status. Plant and Soil, 48: 409-416.

Wiedenfeld, R.P., 1986. Rate, timing, and slow-release nitrogen fertilizers on cabbage and onions. Hort. Sci., 21, 236-238.