Cabbage yield and nutrient uptake

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Like many other shallow-rooted vegetables, cabbage needs an ample supply of water and nutrients to sustain its rapid growth during the last part of the growing cycle. In a field study, we investigated the amounts of nutrients absorbed at different stages of cabbage growth, as affected by rates and timing of nitrogen fertilizer and by addition of the nitrification inhibitor nitrapyrin. Our purpose was to explore ways of reducing nitrogen fertilizer costs and of avoiding nitrate losses from denitrification and leaching.

Cabbage experiment

Some 2,400 acres of cabbage are produced each year in California's Central Coast on a wide variety of soil types, primarily coarser textured soils. The experimental plots were on a Baywood sand. Soil pH was 7.1 and nutrient levels (in parts per million) were 146 for bicarbonate soluble phosphorus, 218 for acetate extractable potassium, and 3.7 for DTPA extractable zinc, indicating a generally sufficient supply of these elements for normal growth.

Each plot was 50 feet long and four beds wide with two plant rows per bed. The fertilizer treatments were replicated four times in a randomized complete block design. Nitrogen fertilizer (ammonium sulfate) was banded into the beds 16 days before transplanting. In the split nitrogen treatments, the second half of the nitrogen was applied after 14 days and two irrigations had occurred following transplanting. The treatments, in pounds of nitrogen per acre, were 0, 45 split, 45 + nitrapyrin, 90, 90 + nitrapyrin, 90 split, 135, 135 + nitrapyrin, 135 split, and 180 split. Nitrapyrin was injected into the ammonium sulfate band at the rate of 0.5 pound per acre in a 10 percent aqueous solution.

Midrib leaf samples were taken before heading, at early heading, and before harvest. Whole top samples were taken from 0, 45, 90, 135, and 180 split plots at two-week intervals from transplanting through harvest; dry weights of oven-dried samples were determined. This plant material was analyzed for total concentrations of nitrogen, phosphorus, potassium, calcium, and magnesium.

TABLE 1. Cabbage midrib nitrate-nitrogen levels and yields as affected by nitrogen rates, timing, and nitrapyrin

Nitrogen rate	Midrib nitrate-nitrogen* Preheading	Heading	Preharvest	Yield*†
lb/acre	*ppm*			*tons/acre*
0	3,812 a	1,770 a	357 a	12.7 a
45 split	5,900 b	2,940 b	525 a	17.6 b
45 single + nitrapyrin‡	8,207 cd	5,605 c	1,195 b	22.0 c
90 single	7,310 c	5,167 c	890 ab	21.2 c
90 single + nitrapyrin	1,207 e	6,735 de	1,492 b	26.7 d
90 split	9,462 d	6,165 cd	1,397 b	26.7 d
135 single + nitrapyrin	12,645 e	7,799 ef	2,825 d	28.6 d
135 single	9,537 d	6,532 d	2,105 c	25.2 d
135 split	10,832 ed	7,790 ef	2,167 c	27.8 d
180 split	11,322 e	8,210 f	2,542 cd	29.0 d

* Means followed by different letters down columns are significantly different by Duncan's multiple range test at the 1 percent level.
† Fresh weight.
‡ Rate of 0.5 pound per acre.

TABLE 2. Cabbage aboveground dry matter production as influenced by nitrogen rates

Days from transplanting	Nitrogen split application (lb/acre)* 0	45	90	135	180
	lb/acre				
0	27 a	27 a	27 a	27 a	27 a
14	142 a	152 a	243 b	268 b	272 b
28	704 a	788 b	1,605 c	1,598 c	1,584 c
42	1,432 a	2,332 b	3,573 c	3,369 c	3,516 c
56	2,641 a	4,265 b	8,174 c	8,091 c	8,164 c

* Means followed by different letters by row were determined to be significantly different by Duncan's multiple range test at 1% level.

TABLE 3. Nutrient uptake by cabbage, as influenced by nitrogen application rates

Nutrient, days after transplanting	Uptake under nitrogen (lb/acre) split application* 0	45	90	135	180
	lb/acre				
0					
Nitrogen	0.83 a	0.82 a	0.81 a	0.83 a	0.83 a
Phosporus	0.1 a	0.1 a	0.1 a	0.1 a	0.1 a
Potassium	0.4 a	0.5 a	0.4 a	0.5 a	0.5 a
Calcium	0.5 a	0.5 a	0.5 a	0.5 a	0.5 a
Magnesium	0.15 a	0.15 a	0.15 a	0.15 a	0.15 a
14					
Nitrogen	3.6 a	5.5 b	9.8 c	11.0 c	11.9 c
Phosphorus	0.6 a	0.7 a	1.1 b	1.4 b	1.4 b
Potassium	2.3 a	3.5 b	5.7 c	6.5 c	6.1 c
Calcium	2.3 a	3.7 b	7.0 c	8.1 c	8.8 c
Magnesium	0.7 a	1.2 b	2.6 c	2.9 c	3.0 c
28					
Nitrogen	30.7 a	38.6 b	80.2 c	80.0 c	80.1 c
Phosphorus	2.9 a	3.5 b	7.1 c	6.7 c	6.8 c
Potassium	20.9 a	28.6 b	48.6 c	47.8 c	50.3 c
Calcium	23.0 a	36.0 b	52.2 c	54.8 c	51.5 c
Magnesium	8.6 a	10.8 b	19.3 c	21.0 c	20.1 c
42					
Nitrogen	43.0 a	72.5 b	156.1 c	155.0 c	158.2 c
Phosphorus	5.4 a	9.6 b	15.7 c	14.2 c	15.1 c
Potassium	33.8 a	53.2 b	93.6 c	93.7 c	91.4 c
Calcium	42.2 a	61.8 b	110.0 c	104.8 c	110.4 c
Magnesium	14.2 a	20.5 b	31.3 c	34.7 c	33.1 c
56					
Nitrogen	50.0 a	121.6 b	244.0 c	261.5 c	270.8 c
Phosphorus	13.7 a	25.2 b	49.0 c	49.4 c	49.1 c
Potassium	85.8 a	152.2 b	307.9 c	306.5 c	302.0 c
Calcium	47.5 a	72.5 b	176.7 c	183.7 c	186.1 c
Magnesium	17.7 a	27.3 b	58.0 c	66.3 c	62.9 c

* Means followed by different letters across a row are significantly different by Duncan's multiple range test at the 1 percent level.

Cabbage heads were harvested from 50 feet of bed in three harvests as they reached market size.

Midrib nitrate-nitrogen (NO_3-N) levels proved to be a reliable guide to the nitrogen status of this crop when compared with yield (table 1). On the first two sampling dates, plots with significantly lower yield also had significantly lower nitrate-nitrogen levels. In the third sampling, near harvest, some of these differences had diminished.

Cabbage yields increased significantly as the nitrogen was increased to the 90 split and 90 + nitrapyrin rates. At higher rates, there was a trend toward higher yields, but also toward undesirable larger head sizes. At the 45-pound rate, plots with nitrapyrin yielded significantly more than those without nitrapyrin, producing about the same yield and head size as are common in commercial fields. At the 90-pound rate, yields in single-application nitrogen plots with nitrapyrin were significantly higher than in those without it, but not higher than in split-application nitrogen-only plots.

Dry matter production increased significantly, starting 14 days after transplanting as nitrogen rates increased to 90 pounds per acre (table 2).

Nitrogen uptake increased significantly with rates up to 90 pounds and showed a trend toward increases at higher application rates (table 3). Uptake of phosphorus, potassium, and, to a lesser extent, calcium and magnesium increased significantly with time and with increases in nitrogen rates up to 90 pounds, then leveled off. The results indicate very rapid absorption of these nutrients during the last part of the growing season.

The common use of triple fertilizer combinations such as 12-12-12 is not validated by this study. Plants take up nitrogen and potassium in roughly equal amounts, and they take up about 80 percent less phosphorus than nitrogen or potassium. Our soil analyses over the years in this region show rising levels of soil phosphorus and a trend toward lower potassium levels. Calcium and magnesium deficiencies are unknown in the area. Both elements are essential for plant growth, however, and significant amounts are taken up with each crop, indicating a need to maintain adequate levels in the soil.

Conclusions

A single application of nitrogen before transplanting proved to be the least effective method of fertilizing cabbage at rates of 90 and 135 pounds per acre. Cabbage yields increased significantly as rates increased from 0 to 90 pounds nitrogen per acre in split applications and 90 pounds nitrogen single application plus nitrapyrin. Adding nitrapyrin to ammonium sulfate bands in single pretransplant applications resulted in significant yield increases over split treatments at 45 pounds of nitrogen and over 90 pounds of nitrogen in a single application.

Absorption of nitrogen, phosphorus, potassium, calcium, and magnesium was significantly increased by nitrogen application to 90 pounds per acre. Approximately two-thirds of the absorption of nutrients and dry weight production occurred during the last part of the growing period.

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