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Butterhead Lettuce Variety Performance Trial in a Hydroponic NFT System

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Year-round production combined with higher yields per square foot has bolstered lettuce (*Lactuca sativa* L.) to be one of the most popular crops grown hydroponically, with butterhead, loose leaf, and romaine dominating the market (Miller, 2019; Kaiser and Ernst, 2016). Desired crop traits of improved yield, pest and disease resistance, tolerance to abiotic stresses of heat and cold, taste, shelf-life, and improved nutritional value have not only influenced grower trends, but an Economic Research Service report also indicated an 8.2% market increase in living butterheads and pre-packaged lettuce mixes among consumers annually (ERS, 2019). While living butterheads are exclusive to hydroponic production, the interaction between varietal selection and water fertility levels is not thoroughly studied. A 2019 hydroponic fertility study found increased fresh weight of 'Mirlo' with increased phosphate levels, whereas fresh weight decreased in 'Rex', a hydroponic lettuce variety standard (Singh et al., 2019). Data-driven recommendations for living butterhead optimization in hydroponic production systems are needed to guide grower decisions on fertility requirements, varietal selection, and potential marketable yield. Our objectives of this study were to 1) understand the relationship of butterhead lettuce variety preference and nitrogen fertility treatments, and 2) provide varietal recommendations for optimum butterhead lettuce production in small-scale hydroponics.

Materials and Methods

Research was conducted at the University of Minnesota's Plant Growth Facility greenhouses in St. Paul, Minnesota. Twelve identical nutrient film technique (NFT) systems were obtained from Crop King Inc. (Lodi, Ohio), which consisted of six 4 ft. long PVC channels and top covers with 36 plant spaces (1 in^2) each. A 25-gallon reservoir accompanied each NFT table for water recirculation.

Fertility concentrations of recommended 5N-12P-26K (Jacks Hydroponic Part A) and high (recommended x 1.5 concentration) were the treatments, and each treatment was replicated six times. Six butterhead lettuce varieties were selected to be grown in the NFT systems based on noted days to maturity (DTM), leaf color, head quality desired, and disease resistance (Table 1). Each variety was grown in both fertility treatments, with a total of 72 plants per variety.

Lettuce plugs were started from seed in rockwool seed cubes and grown for approximately two weeks before transplanting to the NFT channels. Four rounds of hydroponic lettuce production were grown from the spring of 2021 through the winter of 2022, with the avoidance of summer production due to high greenhouse temperatures. Lettuce was harvested at DTM and fresh weights of plants, with roots intact (living butterhead), were recorded. Any damage to lettuce heads including bolting, calcium deficiency, and tip-burn

was characterized as unmarketable, and the mean percent of marketable heads was calculated.

Results and Discussion

There were no differences in the interaction of variety performance and fertility treatments. Mean fresh weight of a single lettuce grown in recommended fertility ranged from 94.8 g to 122.1 g, whereas increasing fertility by 1.5 times in the high treatment produced fresh weights of 80.5 g to 135.3 g.

Fresh weight

Performance differences were found between butterhead varieties (Figure 1). The highest mean fresh weight was 'Buttercrunch', averaging 126.1 g per plant, though it was not statistically different than 'Dynamite', 'Bibb', or 'Mirlo'. A decrease of 22.6 g per plant of fresh weight was found when 'Skyphos' was compared to 'Buttercrunch', however similar fresh weights were found between lettuce varieties of Dynamite, Mirlo, Bibb, and Skyphos. The lowest yielding lettuce variety was Teodore, with mean single plant fresh weight of 87.7 g.

Marketability

Tip burn and bolting occurred throughout the four lettuce production rounds, with increased incidence when greenhouse temperatures were warmer. Recorded observations indicated higher levels of tip-burn and bolting when fertility treatment was high, though fertility treatments were not different statistically. Larger concentrations of inner leaf tip-burn, caused by a calcium-related disorder caused the decrease of marketability to 'Teodore', when fertility treatments were combined (Table 2). Tip-burn was also higher in 'Bibb' but was located on the inner and lower-basal leaves, comparatively. No differences were found between the marketability of 'Buttercrunch', 'Dynamite',' Mirlo', and 'Skyphos'.

Potential fresh weight volume

Based on mean fresh weight and percent marketability, we could project potential fresh weight volume of a single variety planted in one introductory-sized and commercially standard NFT (4-6) hydroponic table, with 36 plant spaces (Table 2). Decreased marketability of 'Bibb' lettuce significantly reduced its potential NFT table fresh weight. In contrast, the 95.1% marketability of 'Skyphos' increased its potential yield to similar values of 'Buttercrunch', 'Dynamite', and 'Mirlo', despite smaller single fresh plant weight.

Summary

Increased fertility concentrations in lettuce varieties provides no benefit to yield and marketability. Maintaining the recommended nutrient fertility levels optimizes yield across butterhead lettuce varieties. Decreased marketability of butterhead lettuce varieties resulted due to bolting and tip burn, a calcium-related disorder caused by heat stress. The varieties of Buttercrunch, Dynamite, Mirlo, and Skyphos seemed to have a better tolerance to warmer greenhouse temperatures, while the varieties of Bibb and Teodore were more symptomatic.

Though preliminary research specifically labeled 'Teodore' for hydroponic production, our research indicated it produced the smallest fresh weight butterheads with decreased marketability and projected yield. Despite its shortfalls, a grower may still want to grow 'Teodore' hydroponically for its unique leaf color, texture, and potential fresh market demand.

The larger single head fresh weight, increased marketability, and market adaptability of 'Buttercrunch' lettuce makes it the recommended lettuce variety to grow in a hydroponic NFT system. Growing a combination of the better performing varieties of Buttercrunch, Dynamite, Mirlo, and Skyphos could also provide small-scale hydroponic growers with a longer harvest period as the DTM is slightly staggered among the four varieties.

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Table 1. Living butterhead lettuce variety selection, days to maturity (DTM), leaf and growing characteristics, and image of head at maturity.

Variety and seed source[z]	DTM	Leaf color	Description	Head at maturity
Bibb[BRP]	55	Green	Heirloom, crisp sweet leaves, suitable for outdoor/indoor production, and cold/heat tolerant	
Buttercrunch[BRP]	65	Green	Improved bibb type, tightly bunched, slow to bolt with some heat tolerance	
Dynamite[BRP]	65	Green	Soft overlapped leaves with sweet flavor and high beta-carotene, Nr:0[y], blight and downy mildew resistance	
Mirlo[JHN]	52	Pale green	Large tender leaves, some heat tolerance, Nr:0 and internal tip burn resistance	
Skyphos[JHN]	47	Dark red with lime-green heart	Most adaptable for indoor/outdoor production, Nr:0 and downy mildew resistance	
Teodore[PAR]	50	Red	Large framed and medium-thick leaves, recommended for hydroponic production, downy mildew resistance	

[z]BRP=W. Atlee Burpee & Co., JHN=Johnny's Selected Seeds, and PAR=Paramount Seeds.
[y]Nr:0=aphid resistance gene.

Table 2. Mean percent marketability and potential yield of butterhead lettuce varieties grown in a single NFT (4-6) hydroponic system.

Variety	Marketability (%)	Potential yield (g)
Bibb	67.9 b[z]	2635.6 b
Buttercrunch	87.5 a	3972.2 a
Dynamite	86.2 a	3749.1 a
Mirlo	88.0 a	3515.3 a
Skyphos	95.1 a	3541.6 a
Teodore	75.4 b	2379.9 b

[z]Means followed by the same letter in the same column are not different from one another.

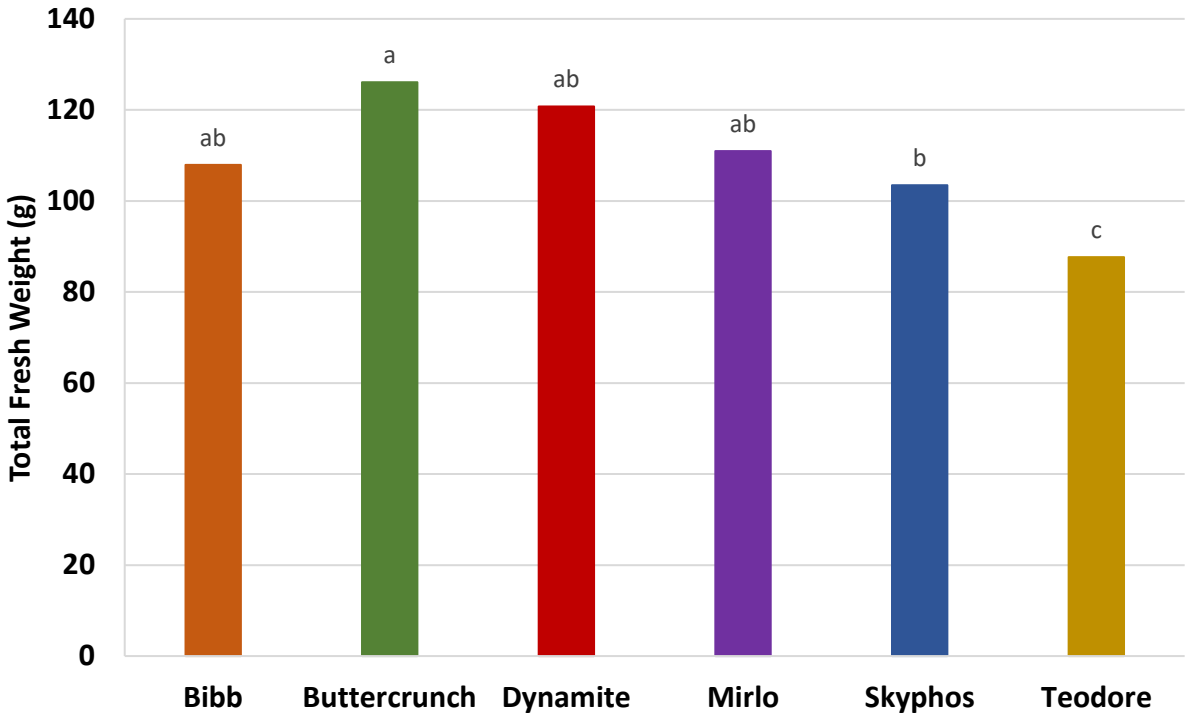

Figure 1. Mean fresh weight (g) of lettuce varieties from a single butterhead. Means with the same letter are not different (P< 0.05) among varieties.

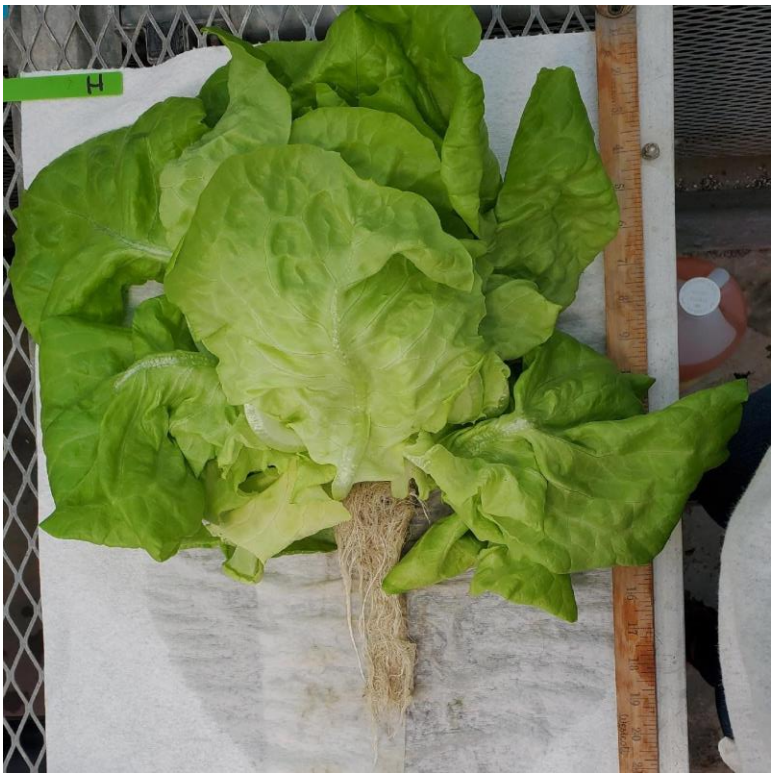

Figure 2. Living butterhead harvested at maturity.

Figure 3. Second round of six lettuce varieties grown in NFT systems at the University of Minnesota, during spring of 2021.