1. Data import and device

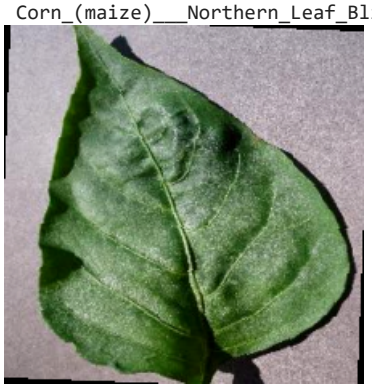
2.Data visualization

show image amount, show class amount,and batch size

```
Total images: 35725  |  Train: 28580  Val: 7145
Num classes: 23
Classes: ['Apple___Apple_scab', 'Apple___Black_rot', 'Apple___Cedar_apple_rust', 'Apple___healthy', 'Corn_(maize)___Ce
rcospora_leaf_spot Gray_leaf_spot', 'Corn_(maize)___Common_rust_', 'Corn_(maize)___Northern_Leaf_Blight', 'Corn_(maiz
e)___healthy', 'Pepper__bell___Bacterial_spot', 'Pepper__bell___healthy', 'Potato___Early_blight', 'Potato___Late_blig
ht', 'Potato___healthy', 'Tomato_Bacterial_spot', 'Tomato_Early_blight', 'Tomato_Late_blight', 'Tomato_Leaf_Mold', 'To
mato_Septoria_leaf_spot', 'Tomato_Spider_mites_Two_spotted_spider_mite', 'Tomato__Target_Spot', 'Tomato__Tomato_Yellow
Leaf__Curl_Virus', 'Tomato__Tomato_mosaic_virus', 'Tomato_healthy']
Batch: torch.Size([256, 3, 224, 224]) torch.Size([256])
```

Display the first 10 images from the dataset.

Corn_(maize)___Northern_Leaf_Blight



Pepper__bell___healthy

Apple___Cedar_apple_rust

Tomato__Tomato_YellowLeaf__Curl_Virus

Corn_(maize)___healthy

Tomato__Tomato_YellowLeaf__Curl_Virus

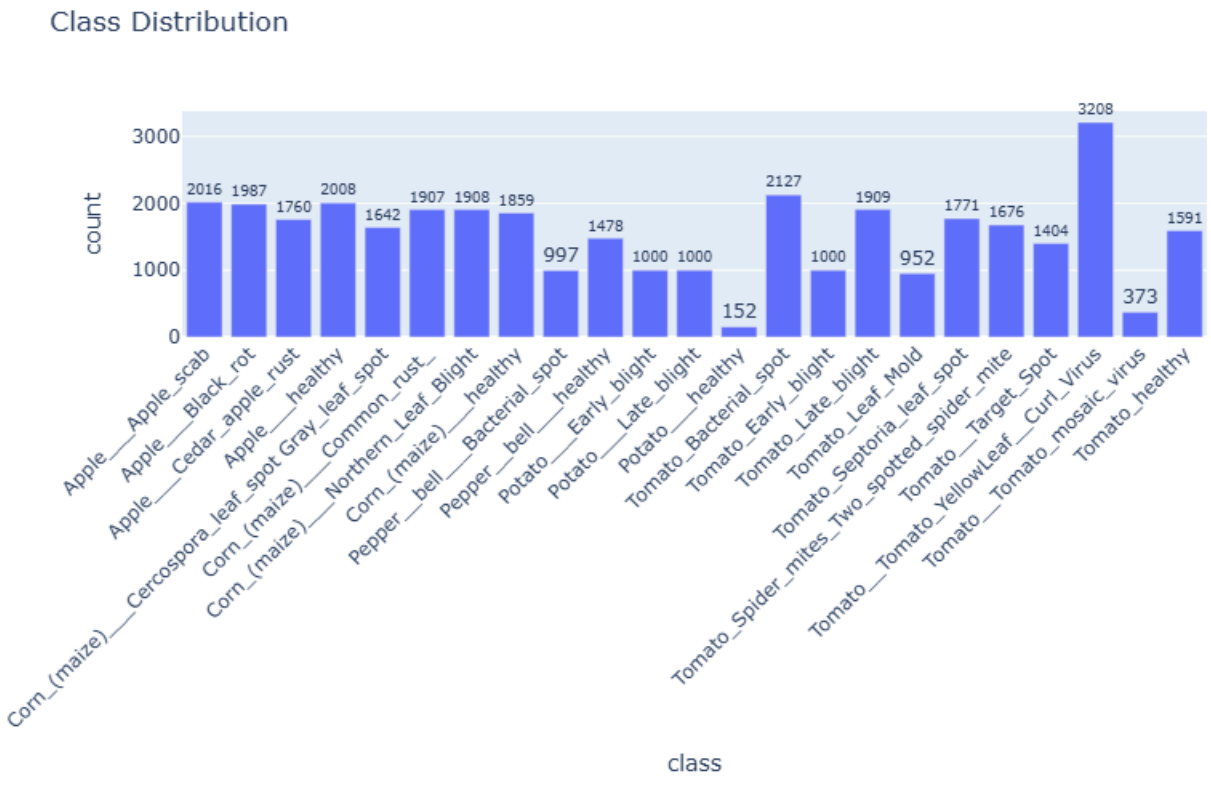
Tomato_Early_blight

```
Apple___healthy
```

```
Corn_(maize)___Cercospora_leaf_spot Gray_leaf_spot
```

Count images per class to check class balance.

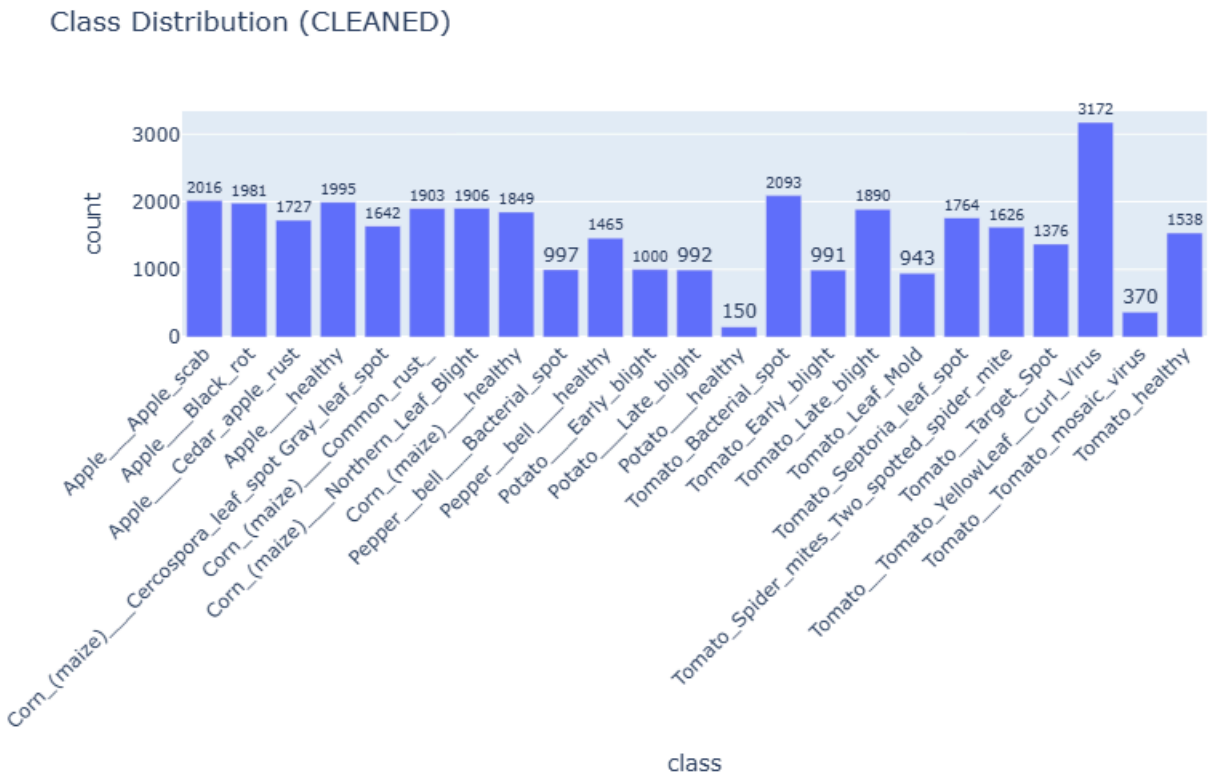
```
Counter({'Tomato__Tomato_YellowLeaf__Curl_Virus': 3208, 'Tomato_Bacterial_spot': 2127, 'Apple___Apple_scab': 2016, 'Apple___healthy': 2008, 'Apple___Black_rot': 1987, 'Tomato_Late_blight': 1909, 'Corn_(maize)___Northern_Leaf_Blight': 1908, 'Corn_(maize)___Common_rust_': 1907, 'Corn_(maize)___healthy': 1859, 'Tomato_Septoria_leaf_spot': 1771, 'Apple___Cedar_apple_rust': 1760, 'Tomato_Spider_mites_Two_spotted_spider_mite': 1676, 'Corn_(maize)___Cercospora_leaf_spot Gray_leaf_spot': 1642, 'Tomato_healthy': 1591, 'Pepper__bell___healthy': 1478, 'Tomato__Target_Spot': 1404, 'Potato___Early_blight': 1000, 'Potato___Late_blight': 1000, 'Tomato_Early_blight': 1000, 'Pepper__bell___Bacterial_spot': 997, 'Tomato_Leaf_Mold': 952, 'Tomato__Tomato_mosaic_virus': 373, 'Potato___healthy': 152})
```



3. Data cleaning

```
Scanning: 100%|██████████| 35725/35725 [00:55<00:00, 644.34it/s]
=== Clean Summary ===
{'total_found': 35725, 'copied': 35386, 'skipped_unreadable': 0, 'skipped_too_small': 0, 'skipped_other': 339, 'by_cla
ss': {'Apple___Apple_scab': 2016, 'Apple___Black_rot': 1981, 'Apple___Cedar_apple_rust': 1727, 'Apple___healthy': 199
5, 'Corn_(maize)___Cercospora_leaf_spot Gray_leaf_spot': 1642, 'Corn_(maize)___Common_rust_': 1903, 'Corn_(maize)___No
rthern_Leaf_Blight': 1906, 'Corn_(maize)___healthy': 1849, 'Pepper__bell___Bacterial_spot': 997, 'Pepper__bell___healt
hy': 1465, 'Potato___Early_blight': 1000, 'Potato___Late_blight': 992, 'Potato___healthy': 150, 'Tomato_Bacterial_spo
t': 2093, 'Tomato_Early_blight': 991, 'Tomato_Late_blight': 1890, 'Tomato_Leaf_Mold': 943, 'Tomato_Septoria_leaf_spo
t': 1764, 'Tomato_Spider_mites_Two_spotted_spider_mite': 1626, 'Tomato__Target_Spot': 1376, 'Tomato__Tomato_YellowLeaf
__Curl_Virus': 3172, 'Tomato__Tomato_mosaic_virus': 370, 'Tomato_healthy': 1538}}
Unreadable: 0 | Too small: 0 | Dup(same class): 179 | Dup(cross class): 160
```

```
-- unreadable (showing up to 5) --

-- too_small (showing up to 5) --

-- dup_same_class (showing up to 5) --
('Apple___Black_rot', '/content/Dataset/Apple___Black_rot/769283e3-f7ec-4e62-b907-4b22d1bda1ea___JR_FrgE.S 8618.JPG',
'/content/Dataset/Apple___Black_rot/68566f26-8158-4fd5-9c5f-0a29eec5225a___JR_FrgE.S 8746.JPG')
('Apple___Black_rot', '/content/Dataset/Apple___Black_rot/6f38c615-281d-4bf5-8d92-7c02d3ef9e1b___JR_FrgE.S 8753_270de
g.JPG', '/content/Dataset/Apple___Black_rot/4db50338-6897-4d69-8147-717cae13879c___JR_FrgE.S 8645_270deg.JPG')
('Apple___Black_rot', '/content/Dataset/Apple___Black_rot/3d33710d-c091-4dae-a491-ef813ea2d34b___JR_FrgE.S 2885_90deg.
JPG', '/content/Dataset/Apple___Black_rot/977c9b03-47f2-412d-a73d-7e647e973336___JR_FrgE.S 2887_90deg.JPG')
('Apple___Black_rot', '/content/Dataset/Apple___Black_rot/68566f26-8158-4fd5-9c5f-0a29eec5225a___JR_FrgE.S 8746_270de
g.JPG', '/content/Dataset/Apple___Black_rot/769283e3-f7ec-4e62-b907-4b22d1bda1ea___JR_FrgE.S 8618_270deg.JPG')
('Apple___Black_rot', '/content/Dataset/Apple___Black_rot/b371e9c4-177b-4bfb-9430-e14f9f30a06d___JR_FrgE.S 2803_new30d
egFlipLR.JPG', '/content/Dataset/Apple___Black_rot/f3bbe1b6-4a5c-45d4-9660-d24b8c43f2fc___JR_FrgE.S 2806_new30degFlipL
R.JPG')

-- dup_cross_class (showing up to 5) --
('Apple___Black_rot', '/content/Dataset/Apple___Black_rot/65e6c212-6363-4ba2-8245-52c5266efad0___JR_FrgE.S 8625_90deg.
JPG', 'Apple___Apple_scab', '/content/Dataset/Apple___Apple_scab/e8f5c962-6f40-443e-9913-5a43b5f2ef07___FREC_Scab 319
1.JPG')
('Apple___healthy', '/content/Dataset/Apple___healthy/2b21526f-9ab0-444b-829a-fa97cd727733___RS_HL 7844.JPG', 'Apple__
_Cedar_apple_rust', '/content/Dataset/Apple___Cedar_apple_rust/85f1b51d-ad5e-4ec2-a46b-2a9dade22e2a___FREC_C.Rust 9971
_newGRR.JPG')
('Corn_(maize)___healthy', '/content/Dataset/Corn_(maize)___healthy/515cfd7f-995c-4843-93f7-dc2c012db476___R.S_HL 7877
copy 2_flipLR.jpg', 'Apple___healthy', '/content/Dataset/Apple___healthy/d76e79e5-2cd5-4a03-9354-5759b2741210___RS_HL
7980.JPG')
('Corn_(maize)___healthy', '/content/Dataset/Corn_(maize)___healthy/5a2800a4-15ed-43a5-864d-01d16d37ed67___R.S_HL 8219
copy.jpg', 'Apple___Cedar_apple_rust', '/content/Dataset/Apple___Cedar_apple_rust/d4547913-b1ce-4620-b078-dbf24ea71764
___FREC_C.Rust 4197_newGRR.JPG')
('Corn_(maize)___healthy', '/content/Dataset/Corn_(maize)___healthy/ab90a3d7-ab29-4efe-a5f1-b9817b09d4e2___R.S_HL 5541
copy 2_flipLR.jpg', 'Apple___Cedar_apple_rust', '/content/Dataset/Apple___Cedar_apple_rust/57a522fe-b1f4-47e0-9b4c-b30
635b402f7___FREC_C.Rust 4226_90deg.JPG')
```



```
Total after cleaning: 35386

Class order: {'Apple___Apple_scab': 0, 'Apple___Black_rot': 1, 'Apple___Cedar_apple_rust': 2, 'Apple___healthy': 3, 'C
orn_(maize)___Cercospora_leaf_spot Gray_leaf_spot': 4, 'Corn_(maize)___Common_rust_': 5, 'Corn_(maize)___Northern_Leaf
_Blight': 6, 'Corn_(maize)___healthy': 7, 'Pepper__bell___Bacterial_spot': 8, 'Pepper__bell___healthy': 9, 'Potato___E
arly_blight': 10, 'Potato___Late_blight': 11, 'Potato___healthy': 12, 'Tomato_Bacterial_spot': 13, 'Tomato_Early_bligh
t': 14, 'Tomato_Late_blight': 15, 'Tomato_Leaf_Mold': 16, 'Tomato_Septoria_leaf_spot': 17, 'Tomato_Spider_mites_Two_sp
otted_spider_mite': 18, 'Tomato__Target_Spot': 19, 'Tomato__Tomato_YellowLeaf__Curl_Virus': 20, 'Tomato__Tomato_mosaic
_virus': 21, 'Tomato_healthy': 22}
Counts: [2016 1981 1727 1995 1642 1903 1906 1849  997 1465 1000  992  150 2093
  991 1890  943 1764 1626 1376 3172  370 1538] | imbalance ratio (max/min): 21.147
USE_SAMPLER = True
RandAugment enabled.

CLEAN train batch: torch.Size([256, 3, 224, 224]) | y type: <class 'torch.Tensor'>
```

4. Model and comparison model

ResNet50

EfficientNetB0

Our own 20-layer CNN Model

5. Model training

```
Training on: cuda


======================================================================
TRAINING RESNET50
======================================================================
Downloading: "https://download.pytorch.org/models/resnet50-0676ba61.pth" to /root/.cache/torch/hub/checkpoints/resnet5
0-0676ba61.pth
```

```
100%|██████████| 97.8M/97.8M [00:00<00:00, 229MB/s]
Starting training for resnet50...
----------------------------------------------------------------------
Epoch  1/30 | Train Loss: 0.3804 Acc:  88.33% | Val Loss: 0.4168 Acc:  88.65% ✓ [Best: 88.65%]
Epoch  2/30 | Train Loss: 0.1456 Acc:  95.29% | Val Loss: 0.2275 Acc:  93.56% ✓ [Best: 93.56%]
Epoch  3/30 | Train Loss: 0.1363 Acc:  95.54% | Val Loss: 0.1315 Acc:  95.52% ✓ [Best: 95.52%]
Epoch  4/30 | Train Loss: 0.1065 Acc:  96.53% | Val Loss: 0.1365 Acc:  95.05%
Epoch  5/30 | Train Loss: 0.0963 Acc:  96.97% | Val Loss: 0.1582 Acc:  94.50%
Epoch  6/30 | Train Loss: 0.0890 Acc:  97.05% | Val Loss: 0.0920 Acc:  97.02% ✓ [Best: 97.02%]
Epoch  7/30 | Train Loss: 0.0791 Acc:  97.43% | Val Loss: 0.2210 Acc:  93.32%
Epoch  8/30 | Train Loss: 0.0892 Acc:  97.09% | Val Loss: 0.2302 Acc:  92.53%
Epoch  9/30 | Train Loss: 0.0824 Acc:  97.20% | Val Loss: 0.1056 Acc:  96.66%
Epoch 10/30 | Train Loss: 0.0735 Acc:  97.59% | Val Loss: 0.1034 Acc:  96.78%
Epoch 11/30 | Train Loss: 0.0381 Acc:  98.79% | Val Loss: 0.0284 Acc:  99.02% ✓ [Best: 99.02%]
Epoch 12/30 | Train Loss: 0.0305 Acc:  98.99% | Val Loss: 0.0207 Acc:  99.36% ✓ [Best: 99.36%]
Epoch 13/30 | Train Loss: 0.0253 Acc:  99.21% | Val Loss: 0.0591 Acc:  98.11%
Epoch 14/30 | Train Loss: 0.0258 Acc:  99.17% | Val Loss: 0.0268 Acc:  99.13%
Epoch 15/30 | Train Loss: 0.0360 Acc:  98.81% | Val Loss: 0.0416 Acc:  98.59%
Epoch 16/30 | Train Loss: 0.0393 Acc:  98.80% | Val Loss: 0.0325 Acc:  99.03%
Epoch 17/30 | Train Loss: 0.0191 Acc:  99.45% | Val Loss: 0.0138 Acc:  99.59% ✓ [Best: 99.59%]
Epoch 18/30 | Train Loss: 0.0143 Acc:  99.57% | Val Loss: 0.0160 Acc:  99.57%
Epoch 19/30 | Train Loss: 0.0138 Acc:  99.57% | Val Loss: 0.0130 Acc:  99.57%
Epoch 20/30 | Train Loss: 0.0160 Acc:  99.52% | Val Loss: 0.0140 Acc:  99.64% ✓ [Best: 99.64%]
Epoch 21/30 | Train Loss: 0.0143 Acc:  99.59% | Val Loss: 0.0172 Acc:  99.43%
Epoch 22/30 | Train Loss: 0.0154 Acc:  99.54% | Val Loss: 0.0143 Acc:  99.54%
Epoch 23/30 | Train Loss: 0.0173 Acc:  99.42% | Val Loss: 0.0168 Acc:  99.47%
Epoch 24/30 | Train Loss: 0.0104 Acc:  99.73% | Val Loss: 0.0106 Acc:  99.72% ✓ [Best: 99.72%]
Epoch 25/30 | Train Loss: 0.0079 Acc:  99.81% | Val Loss: 0.0096 Acc:  99.78% ✓ [Best: 99.78%]
Epoch 26/30 | Train Loss: 0.0060 Acc:  99.84% | Val Loss: 0.0119 Acc:  99.71%
Epoch 27/30 | Train Loss: 0.0068 Acc:  99.82% | Val Loss: 0.0116 Acc:  99.73%
Epoch 28/30 | Train Loss: 0.0089 Acc:  99.73% | Val Loss: 0.0125 Acc:  99.64%
Epoch 29/30 | Train Loss: 0.0081 Acc:  99.77% | Val Loss: 0.0124 Acc:  99.68%
Epoch 30/30 | Train Loss: 0.0064 Acc:  99.83% | Val Loss: 0.0092 Acc:  99.76%

Early stopping at epoch 30
Best validation accuracy: 99.78% (epoch 25)

Training complete! Best model saved as 'best_resnet50.pth'
----------------------------------------------------------------------

======================================================================
TRAINING EFFICIENTNETB0
======================================================================
Downloading: "https://download.pytorch.org/models/efficientnet_b0_rwightman-7f5810bc.pth" to /root/.cache/torch/hub/ch
eckpoints/efficientnet_b0_rwightman-7f5810bc.pth
100%|██████████| 20.5M/20.5M [00:00<00:00, 197MB/s]
Starting training for efficientnet_b0...
----------------------------------------------------------------------
```

```
Epoch  1/30 | Train Loss: 0.2804 Acc:  92.61% | Val Loss: 0.0713 Acc:  97.75% ✓ [Best: 97.75%]
Epoch  2/30 | Train Loss: 0.0669 Acc:  97.88% | Val Loss: 0.1049 Acc:  96.95%
Epoch  3/30 | Train Loss: 0.0539 Acc:  98.23% | Val Loss: 0.0360 Acc:  98.80% ✓ [Best: 98.80%]
Epoch  4/30 | Train Loss: 0.0453 Acc:  98.54% | Val Loss: 0.0351 Acc:  98.82% ✓ [Best: 98.82%]
Epoch  5/30 | Train Loss: 0.0417 Acc:  98.69% | Val Loss: 0.0224 Acc:  99.22% ✓ [Best: 99.22%]
Epoch  6/30 | Train Loss: 0.0331 Acc:  98.94% | Val Loss: 0.0356 Acc:  98.98%
Epoch  7/30 | Train Loss: 0.0389 Acc:  98.76% | Val Loss: 0.0194 Acc:  99.34% ✓ [Best: 99.34%]
Epoch  8/30 | Train Loss: 0.0352 Acc:  98.84% | Val Loss: 0.0276 Acc:  99.16%
Epoch  9/30 | Train Loss: 0.0309 Acc:  99.06% | Val Loss: 0.0257 Acc:  99.13%
Epoch 10/30 | Train Loss: 0.0311 Acc:  99.02% | Val Loss: 0.0962 Acc:  97.49%
Epoch 11/30 | Train Loss: 0.0391 Acc:  98.72% | Val Loss: 0.0375 Acc:  98.92%
Epoch 12/30 | Train Loss: 0.0152 Acc:  99.53% | Val Loss: 0.0128 Acc:  99.64% ✓ [Best: 99.64%]
Epoch 13/30 | Train Loss: 0.0112 Acc:  99.64% | Val Loss: 0.0108 Acc:  99.69% ✓ [Best: 99.69%]
Epoch 14/30 | Train Loss: 0.0088 Acc:  99.73% | Val Loss: 0.0107 Acc:  99.66%
Epoch 15/30 | Train Loss: 0.0099 Acc:  99.69% | Val Loss: 0.0151 Acc:  99.52%
Epoch 16/30 | Train Loss: 0.0156 Acc:  99.53% | Val Loss: 0.0142 Acc:  99.62%
Epoch 17/30 | Train Loss: 0.0133 Acc:  99.60% | Val Loss: 0.0155 Acc:  99.54%
Epoch 18/30 | Train Loss: 0.0125 Acc:  99.65% | Val Loss: 0.0111 Acc:  99.68%

Early stopping at epoch 18
Best validation accuracy: 99.69% (epoch 13)

Training complete! Best model saved as 'best_efficientnet_b0.pth'
----------------------------------------------------------------------

======================================================================
TRAINING CUSTOM 20-LAYER CNN MODEL
======================================================================
Initializing 20-layer CNN for 23 classes on device: cuda

Starting training for cnn_20...
----------------------------------------------------------------------
Epoch  1/30 | Train Loss: 3.3456 Acc:   8.26% | Val Loss: 2.9537 Acc:   9.92% ✓ [Best: 9.92%]
Epoch  2/30 | Train Loss: 2.9047 Acc:  12.41% | Val Loss: 2.7448 Acc:  14.23% ✓ [Best: 14.23%]
Epoch  3/30 | Train Loss: 2.5995 Acc:  19.97% | Val Loss: 2.3030 Acc:  28.37% ✓ [Best: 28.37%]
Epoch  4/30 | Train Loss: 2.1540 Acc:  33.24% | Val Loss: 1.7290 Acc:  47.21% ✓ [Best: 47.21%]
Epoch  5/30 | Train Loss: 1.8915 Acc:  40.43% | Val Loss: 1.6162 Acc:  53.41% ✓ [Best: 53.41%]
Epoch  6/30 | Train Loss: 1.7339 Acc:  45.05% | Val Loss: 1.3532 Acc:  58.88% ✓ [Best: 58.88%]
Epoch  7/30 | Train Loss: 1.5777 Acc:  50.15% | Val Loss: 1.3091 Acc:  62.58% ✓ [Best: 62.58%]
Epoch  8/30 | Train Loss: 1.4554 Acc:  54.39% | Val Loss: 1.7604 Acc:  43.88%
Epoch  9/30 | Train Loss: 1.3677 Acc:  57.17% | Val Loss: 1.1050 Acc:  67.28% ✓ [Best: 67.28%]
Epoch 10/30 | Train Loss: 1.2413 Acc:  61.00% | Val Loss: 1.4380 Acc:  63.36%
Epoch 11/30 | Train Loss: 1.1689 Acc:  63.82% | Val Loss: 1.1967 Acc:  61.50%
Epoch 12/30 | Train Loss: 1.1991 Acc:  63.92% | Val Loss: 1.5171 Acc:  67.15%
Epoch 13/30 | Train Loss: 1.9339 Acc:  45.92% | Val Loss: 1.2787 Acc:  60.88%
Epoch 14/30 | Train Loss: 1.1903 Acc:  62.75% | Val Loss: 0.8121 Acc:  77.33% ✓ [Best: 77.33%]
Epoch 15/30 | Train Loss: 0.9802 Acc:  68.88% | Val Loss: 0.6584 Acc:  79.87% ✓ [Best: 79.87%]
Epoch 16/30 | Train Loss: 0.8720 Acc:  72.12% | Val Loss: 0.5590 Acc:  82.28% ✓ [Best: 82.28%]
Epoch 17/30 | Train Loss: 0.8072 Acc:  74.51% | Val Loss: 0.7214 Acc:  77.65%
Epoch 18/30 | Train Loss: 0.7316 Acc:  76.60% | Val Loss: 0.4827 Acc:  84.76% ✓ [Best: 84.76%]
Epoch 19/30 | Train Loss: 0.6658 Acc:  78.88% | Val Loss: 0.4548 Acc:  85.44% ✓ [Best: 85.44%]
Epoch 20/30 | Train Loss: 0.6204 Acc:  80.06% | Val Loss: 0.3624 Acc:  88.23% ✓ [Best: 88.23%]
Epoch 21/30 | Train Loss: 0.5844 Acc:  81.22% | Val Loss: 0.4383 Acc:  85.28%
Epoch 22/30 | Train Loss: 0.5525 Acc:  82.33% | Val Loss: 0.3234 Acc:  89.62% ✓ [Best: 89.62%]
Epoch 23/30 | Train Loss: 0.5189 Acc:  83.45% | Val Loss: 0.3385 Acc:  89.31%
Epoch 24/30 | Train Loss: 0.5003 Acc:  84.09% | Val Loss: 0.6970 Acc:  84.63%
Epoch 25/30 | Train Loss: 0.4816 Acc:  84.66% | Val Loss: 0.2839 Acc:  90.90% ✓ [Best: 90.90%]
Epoch 26/30 | Train Loss: 0.4607 Acc:  85.13% | Val Loss: 0.2531 Acc:  91.66% ✓ [Best: 91.66%]
Epoch 27/30 | Train Loss: 0.4357 Acc:  86.00% | Val Loss: 0.2987 Acc:  89.92%
Epoch 28/30 | Train Loss: 0.4265 Acc:  86.45% | Val Loss: 0.2327 Acc:  92.53% ✓ [Best: 92.53%]
Epoch 29/30 | Train Loss: 0.3970 Acc:  87.23% | Val Loss: 0.2032 Acc:  93.41% ✓ [Best: 93.41%]
Epoch 30/30 | Train Loss: 0.3997 Acc:  87.63% | Val Loss: 0.2714 Acc:  91.67%

Training complete! Best model saved as 'best_cnn_20.pth'
----------------------------------------------------------------------
```

```
======================================================================
SAVING MODELS
======================================================================
Saved resnet50 with metadata to 'resnet50_complete.pth'
Saved efficientnet_b0 with metadata to 'efficientnet_b0_complete.pth'
Saved cnn_20 with metadata to 'cnn_20_complete.pth'

Training complete for all models
Models saved with complete metadata
See Section 6 for detailed performance comparison and analysis
Use ModelInference.ipynb to reload models without retraining
```

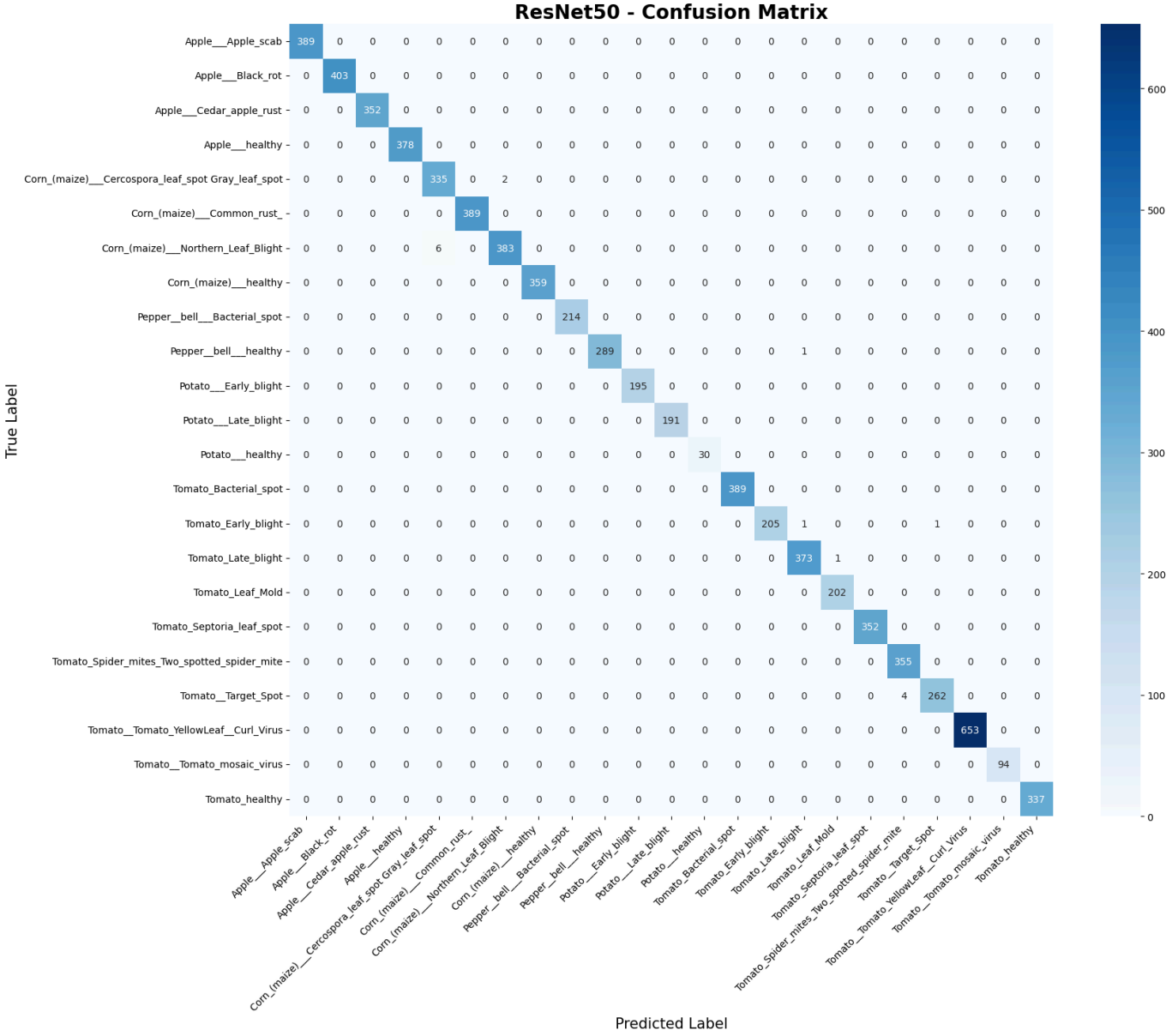
6. Model performance comparison & CV

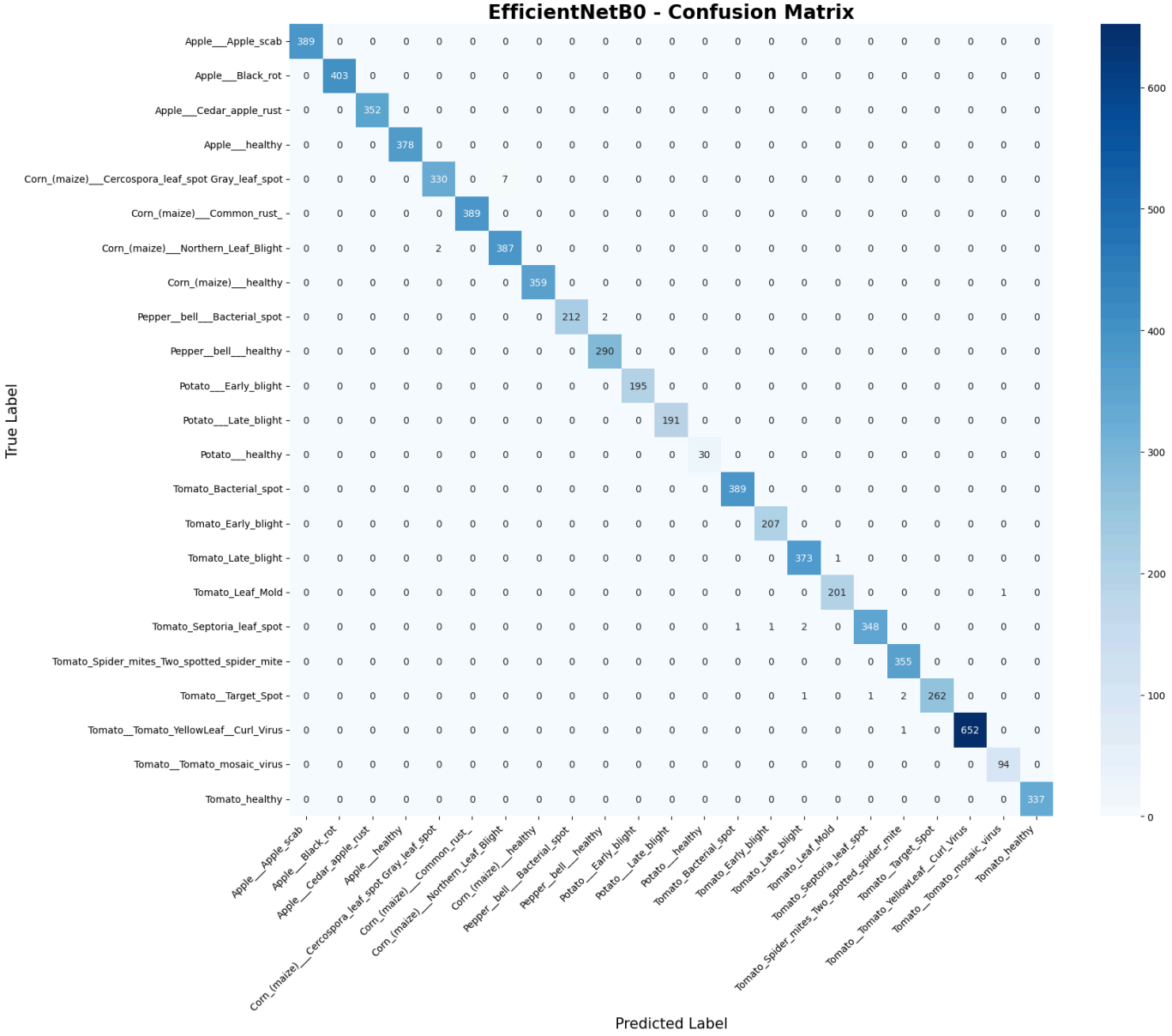
```
Evaluating ResNet50...
Evaluating EfficientNetB0...
Evaluating Custom CNN-20...

======================================================================
MODEL PERFORMANCE COMPARISON
======================================================================
```

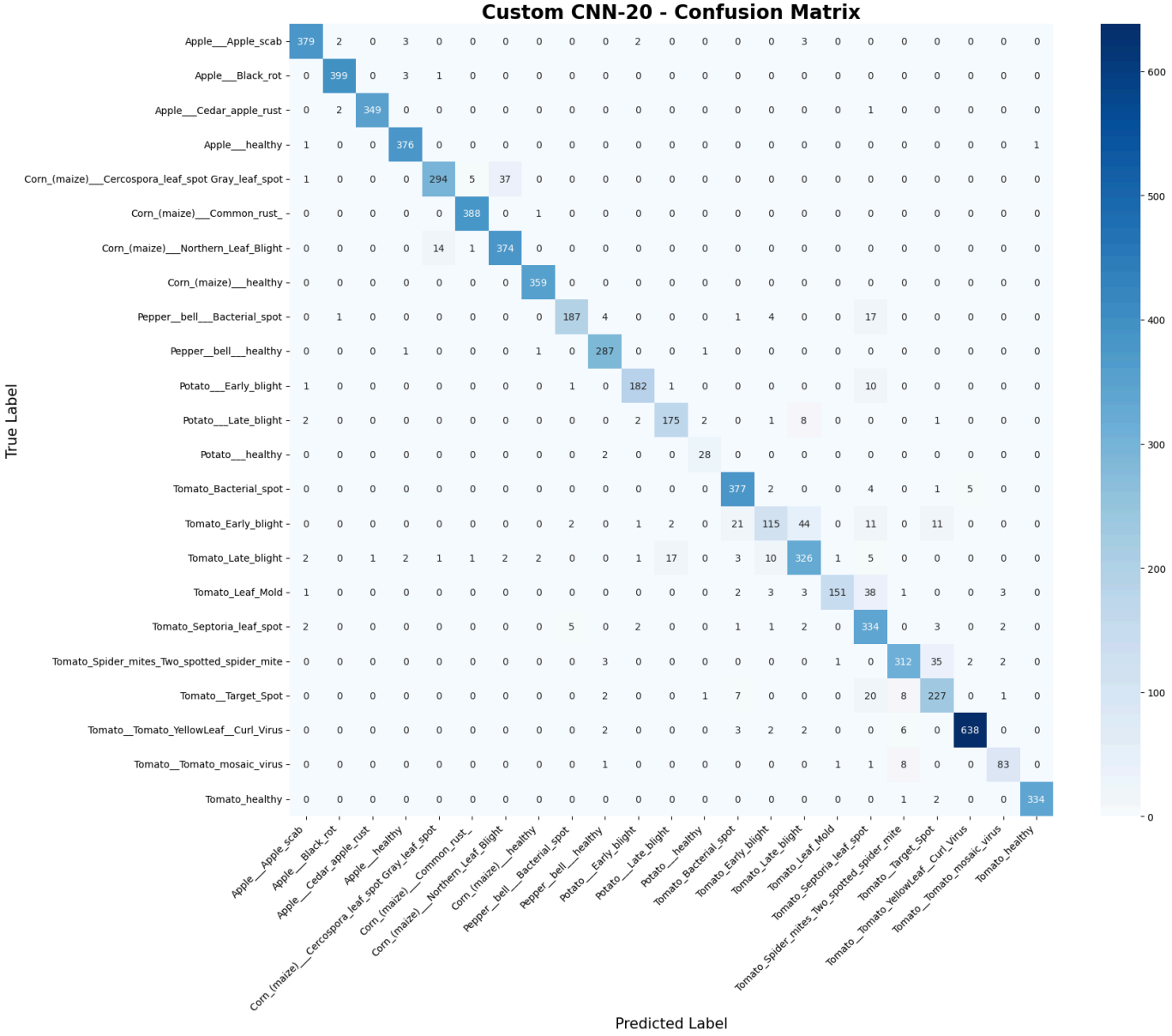
Model	Validation Loss	Validation Accuracy (%)	Top-3 Accuracy (%)
ResNet50	0.0096	99.78	99.97
EfficientNetB0	0.0108	99.69	99.97
Custom CNN-20	0.2032	93.41	99.34

```
======================================================================
RESNET50 CLASSIFICATION REPORT
======================================================================
                                                precision    recall  f1-score   support

                                Apple___Apple_scab      1.000     1.000     1.000       389
                                 Apple___Black_rot      1.000     1.000     1.000       403
                           Apple___Cedar_apple_rust      1.000     1.000     1.000       352
                                    Apple___healthy      1.000     1.000     1.000       378
Corn_(maize)___Cercospora_leaf_spot Gray_leaf_spot      0.982     0.994     0.988       337
                         Corn_(maize)___Common_rust_      1.000     1.000     1.000       389
                Corn_(maize)___Northern_Leaf_Blight      0.995     0.985     0.990       389
                             Corn_(maize)___healthy      1.000     1.000     1.000       359
                      Pepper__bell___Bacterial_spot      1.000     1.000     1.000       214
                             Pepper__bell___healthy      1.000     0.997     0.998       290
                              Potato___Early_blight      1.000     1.000     1.000       195
                               Potato___Late_blight      1.000     1.000     1.000       191
                                   Potato___healthy      1.000     1.000     1.000        30
                             Tomato_Bacterial_spot      1.000     1.000     1.000       389
                               Tomato_Early_blight      1.000     0.990     0.995       207
                                Tomato_Late_blight      0.995     0.997     0.996       374
                                  Tomato_Leaf_Mold      0.995     1.000     0.998       202
                         Tomato_Septoria_leaf_spot      1.000     1.000     1.000       352
       Tomato_Spider_mites_Two_spotted_spider_mite      0.989     1.000     0.994       355
                                Tomato__Target_Spot      0.996     0.985     0.991       266
              Tomato__Tomato_YellowLeaf__Curl_Virus      1.000     1.000     1.000       653
                        Tomato__Tomato_mosaic_virus      1.000     1.000     1.000        94
                                    Tomato_healthy      1.000     1.000     1.000       337

                                          accuracy                          0.998      7145
                                         macro avg      0.998     0.998     0.998      7145
                                      weighted avg      0.998     0.998     0.998      7145


======================================================================
EFFICIENTNETB0 CLASSIFICATION REPORT
======================================================================
                                                precision    recall  f1-score   support

                                Apple___Apple_scab      1.000     1.000     1.000       389
                                 Apple___Black_rot      1.000     1.000     1.000       403
                           Apple___Cedar_apple_rust      1.000     1.000     1.000       352
                                    Apple___healthy      1.000     1.000     1.000       378
Corn_(maize)___Cercospora_leaf_spot Gray_leaf_spot      0.994     0.979     0.987       337
                         Corn_(maize)___Common_rust_      1.000     1.000     1.000       389
                Corn_(maize)___Northern_Leaf_Blight      0.982     0.995     0.989       389
                             Corn_(maize)___healthy      1.000     1.000     1.000       359
                      Pepper__bell___Bacterial_spot      1.000     0.991     0.995       214
                             Pepper__bell___healthy      0.993     1.000     0.997       290
                              Potato___Early_blight      1.000     1.000     1.000       195
                               Potato___Late_blight      1.000     1.000     1.000       191
                                   Potato___healthy      1.000     1.000     1.000        30
                             Tomato_Bacterial_spot      0.997     1.000     0.999       389
                               Tomato_Early_blight      0.995     1.000     0.998       207
                                Tomato_Late_blight      0.992     0.997     0.995       374
                                  Tomato_Leaf_Mold      0.995     0.995     0.995       202
                         Tomato_Septoria_leaf_spot      0.997     0.989     0.993       352
       Tomato_Spider_mites_Two_spotted_spider_mite      0.992     1.000     0.996       355
                                Tomato__Target_Spot      1.000     0.985     0.992       266
              Tomato__Tomato_YellowLeaf__Curl_Virus      1.000     0.998     0.999       653
                        Tomato__Tomato_mosaic_virus      0.989     1.000     0.995        94
                                    Tomato_healthy      1.000     1.000     1.000       337

                                          accuracy                          0.997      7145
                                         macro avg      0.997     0.997     0.997      7145
                                      weighted avg      0.997     0.997     0.997      7145


======================================================================
CUSTOM CNN-20 CLASSIFICATION REPORT
```

```
======================================================================
                                                precision    recall  f1-score   support

                                 Apple___Apple_scab      0.974     0.974     0.974       389
                                  Apple___Black_rot      0.988     0.990     0.989       403
                            Apple___Cedar_apple_rust      0.997     0.991     0.994       352
                                     Apple___healthy      0.977     0.995     0.986       378
Corn_(maize)___Cercospora_leaf_spot Gray_leaf_spot      0.948     0.872     0.909       337
                          Corn_(maize)___Common_rust_      0.982     0.997     0.990       389
                 Corn_(maize)___Northern_Leaf_Blight      0.906     0.961     0.933       389
                           Corn_(maize)___healthy      0.989     1.000     0.994       359
                    Pepper__bell___Bacterial_spot      0.959     0.874     0.914       214
                           Pepper__bell___healthy      0.953     0.990     0.971       290
                            Potato___Early_blight      0.958     0.933     0.945       195
                             Potato___Late_blight      0.897     0.916     0.907       191
                                 Potato___healthy      0.875     0.933     0.903        30
                           Tomato_Bacterial_spot      0.908     0.969     0.938       389
                             Tomato_Early_blight      0.833     0.556     0.667       207
                              Tomato_Late_blight      0.840     0.872     0.856       374
                                Tomato_Leaf_Mold      0.981     0.748     0.848       202
                        Tomato_Septoria_leaf_spot      0.757     0.949     0.842       352
       Tomato_Spider_mites_Two_spotted_spider_mite      0.929     0.879     0.903       355
                              Tomato__Target_Spot      0.811     0.853     0.832       266
             Tomato__Tomato_YellowLeaf__Curl_Virus      0.989     0.977     0.983       653
                       Tomato__Tomato_mosaic_virus      0.912     0.883     0.897        94
                                   Tomato_healthy      0.997     0.991     0.994       337

                                         accuracy                          0.934      7145
                                        macro avg      0.929     0.918     0.920      7145
                                     weighted avg      0.936     0.934     0.933      7145
```


ResNet50 - Confusion Matrix
True Label
Predicted Label
Apple___Apple_scab
Apple___Black_rot
Apple___Cedar_apple_rust
Apple___healthy
Corn_(maize)___Cercospora_leaf_spot Gray_leaf_spot
Corn_(maize)___Common_rust_
Corn_(maize)___Northern_Leaf_Blight
Corn_(maize)___healthy
Pepper__bell___Bacterial_spot
Pepper__bell___healthy
Potato___Early_blight
Potato___Late_blight
Potato___healthy
Tomato_Bacterial_spot
Tomato_Early_blight
Tomato_Late_blight
Tomato_Leaf_Mold
Tomato_Septoria_leaf_spot
Tomato_Spider_mites_Two_spotted_spider_mite
Tomato__Target_Spot
Tomato__Tomato_YellowLeaf__Curl_Virus
Tomato__Tomato_mosaic_virus
Tomato_healthy
600
500
400
300
200
100
0


EfficientNetB0 - Confusion Matrix
True Label
Predicted Label
Apple___Apple_scab
Apple___Black_rot
Apple___Cedar_apple_rust
Apple___healthy
Corn_(maize)___Cercospora_leaf_spot Gray_leaf_spot
Corn_(maize)___Common_rust_
Corn_(maize)___Northern_Leaf_Blight
Corn_(maize)___healthy
Pepper__bell___Bacterial_spot
Pepper__bell___healthy
Potato___Early_blight
Potato___Late_blight
Potato___healthy
Tomato_Bacterial_spot
Tomato_Early_blight
Tomato_Late_blight
Tomato_Leaf_Mold
Tomato_Septoria_leaf_spot
Tomato_Spider_mites_Two_spotted_spider_mite
Tomato__Target_Spot
Tomato__Tomato_YellowLeaf__Curl_Virus
Tomato__Tomato_mosaic_virus
Tomato_healthy
600
500
400
300
200
100
0


Custom CNN-20 - Confusion Matrix
True Label
Predicted Label
Apple___Apple_scab
Apple___Black_rot
Apple___Cedar_apple_rust
Apple___healthy
Corn_(maize)___Cercospora_leaf_spot Gray_leaf_spot
Corn_(maize)___Common_rust_
Corn_(maize)___Northern_Leaf_Blight
Corn_(maize)___healthy
Pepper__bell___Bacterial_spot
Pepper__bell___healthy
Potato___Early_blight
Potato___Late_blight
Potato___healthy
Tomato_Bacterial_spot
Tomato_Early_blight
Tomato_Late_blight
Tomato_Leaf_Mold
Tomato_Septoria_leaf_spot
Tomato_Spider_mites_Two_spotted_spider_mite
Tomato__Target_Spot
Tomato__Tomato_YellowLeaf__Curl_Virus
Tomato__Tomato_mosaic_virus
Tomato_healthy
0
100
200
300
400
500
600

```
======================================================================
STARTING 5-FOLD CROSS-VALIDATION
======================================================================

======================== FOLD 1/5 ========================

Training ResNet50...

Starting training for resnet50_fold1...
----------------------------------------------------------------------
Epoch  1/10 | Train Loss: 0.3649 Acc:  88.60% | Val Loss: 0.1746 Acc:  94.25% ✓ [Best: 94.25%]
Epoch  2/10 | Train Loss: 0.1592 Acc:  94.85% | Val Loss: 0.1621 Acc:  94.63% ✓ [Best: 94.63%]
Epoch  3/10 | Train Loss: 0.1230 Acc:  96.09% | Val Loss: 0.1541 Acc:  95.01% ✓ [Best: 95.01%]
Epoch  4/10 | Train Loss: 0.1043 Acc:  96.56% | Val Loss: 0.8036 Acc:  83.65%
Epoch  5/10 | Train Loss: 0.1042 Acc:  96.61% | Val Loss: 0.1926 Acc:  94.02%
Epoch  6/10 | Train Loss: 0.0799 Acc:  97.34% | Val Loss: 0.1545 Acc:  94.87%

Early stopping at epoch 6
Best validation accuracy: 95.01% (epoch 3)

Training complete! Best model saved as 'best_resnet50_fold1.pth'
----------------------------------------------------------------------
  ResNet50 Fold 1 - Val Acc: 95.01%

Training EfficientNetB0...

Starting training for efficientnet_fold1...
----------------------------------------------------------------------
Epoch  1/10 | Train Loss: 0.2911 Acc:  92.15% | Val Loss: 0.0649 Acc:  97.97% ✓ [Best: 97.97%]
Epoch  2/10 | Train Loss: 0.0622 Acc:  97.98% | Val Loss: 0.0512 Acc:  98.40% ✓ [Best: 98.40%]
Epoch  3/10 | Train Loss: 0.0536 Acc:  98.22% | Val Loss: 0.0338 Acc:  98.95% ✓ [Best: 98.95%]
Epoch  4/10 | Train Loss: 0.0481 Acc:  98.41% | Val Loss: 0.0323 Acc:  99.07% ✓ [Best: 99.07%]
Epoch  5/10 | Train Loss: 0.0345 Acc:  98.89% | Val Loss: 0.0310 Acc:  98.87%
Epoch  6/10 | Train Loss: 0.0351 Acc:  98.90% | Val Loss: 0.0570 Acc:  98.23%
Epoch  7/10 | Train Loss: 0.0387 Acc:  98.74% | Val Loss: 0.0410 Acc:  98.70%

Early stopping at epoch 7
Best validation accuracy: 99.07% (epoch 4)

Training complete! Best model saved as 'best_efficientnet_fold1.pth'
----------------------------------------------------------------------
  EfficientNetB0 Fold 1 - Val Acc: 99.07%

Training Custom CNN-20...

Starting training for cnn20_fold1...
----------------------------------------------------------------------
Epoch  1/10 | Train Loss: 3.2531 Acc:  10.89% | Val Loss: 2.6739 Acc:  14.99% ✓ [Best: 14.99%]
Epoch  2/10 | Train Loss: 2.5924 Acc:  21.09% | Val Loss: 2.1117 Acc:  32.38% ✓ [Best: 32.38%]
Epoch  3/10 | Train Loss: 2.2842 Acc:  29.84% | Val Loss: 1.9252 Acc:  40.80% ✓ [Best: 40.80%]
Epoch  4/10 | Train Loss: 2.1229 Acc:  34.37% | Val Loss: 1.9258 Acc:  40.03%
Epoch  5/10 | Train Loss: 2.0236 Acc:  37.65% | Val Loss: 1.6136 Acc:  51.12% ✓ [Best: 51.12%]
Epoch  6/10 | Train Loss: 1.8706 Acc:  41.67% | Val Loss: 1.5264 Acc:  53.57% ✓ [Best: 53.57%]
Epoch  7/10 | Train Loss: 1.8674 Acc:  43.57% | Val Loss: 1.6134 Acc:  50.07%
Epoch  8/10 | Train Loss: 1.6689 Acc:  48.26% | Val Loss: 2.2238 Acc:  37.64%
Epoch  9/10 | Train Loss: 1.6065 Acc:  50.39% | Val Loss: 1.5907 Acc:  56.54% ✓ [Best: 56.54%]
Epoch 10/10 | Train Loss: 1.8454 Acc:  44.10% | Val Loss: 1.5516 Acc:  53.55%

Training complete! Best model saved as 'best_cnn20_fold1.pth'
----------------------------------------------------------------------
  Custom CNN-20 Fold 1 - Val Acc: 56.54%

======================== FOLD 2/5 ========================

Training ResNet50...

Starting training for resnet50_fold2...
----------------------------------------------------------------------
Epoch  1/10 | Train Loss: 0.3682 Acc:  88.32% | Val Loss: 0.4066 Acc:  87.76% ✓ [Best: 87.76%]
Epoch  2/10 | Train Loss: 0.1526 Acc:  94.96% | Val Loss: 0.2601 Acc:  91.69% ✓ [Best: 91.69%]
```

```
Epoch  3/10 | Train Loss: 0.1252 Acc:  95.84% | Val Loss: 0.1605 Acc:  94.80% ✓ [Best: 94.80%]
Epoch  4/10 | Train Loss: 0.1125 Acc:  96.32% | Val Loss: 0.1168 Acc:  96.40% ✓ [Best: 96.40%]
Epoch  5/10 | Train Loss: 0.0981 Acc:  96.89% | Val Loss: 0.1407 Acc:  95.73%
Epoch  6/10 | Train Loss: 0.0947 Acc:  96.88% | Val Loss: 0.1862 Acc:  93.77%
Epoch  7/10 | Train Loss: 0.0888 Acc:  97.02% | Val Loss: 0.0885 Acc:  97.26% ✓ [Best: 97.26%]
Epoch  8/10 | Train Loss: 0.0808 Acc:  97.31% | Val Loss: 0.1406 Acc:  95.48%
Epoch  9/10 | Train Loss: 0.0808 Acc:  97.40% | Val Loss: 0.0661 Acc:  97.68% ✓ [Best: 97.68%]
Epoch 10/10 | Train Loss: 0.0777 Acc:  97.44% | Val Loss: 0.1150 Acc:  96.23%

Training complete! Best model saved as 'best_resnet50_fold2.pth'
----------------------------------------------------------------------
  ResNet50 Fold 2 - Val Acc: 97.68%

Training EfficientNetB0...

Starting training for efficientnet_fold2...
----------------------------------------------------------------------
Epoch  1/10 | Train Loss: 0.2988 Acc:  92.18% | Val Loss: 0.0704 Acc:  97.43% ✓ [Best: 97.43%]
Epoch  2/10 | Train Loss: 0.0655 Acc:  97.95% | Val Loss: 0.0404 Acc:  98.83% ✓ [Best: 98.83%]
Epoch  3/10 | Train Loss: 0.0481 Acc:  98.46% | Val Loss: 0.0277 Acc:  99.03% ✓ [Best: 99.03%]
Epoch  4/10 | Train Loss: 0.0440 Acc:  98.58% | Val Loss: 0.0699 Acc:  98.28%
Epoch  5/10 | Train Loss: 0.0383 Acc:  98.71% | Val Loss: 0.0439 Acc:  98.64%
Epoch  6/10 | Train Loss: 0.0403 Acc:  98.72% | Val Loss: 0.0349 Acc:  98.80%

Early stopping at epoch 6
Best validation accuracy: 99.03% (epoch 3)

Training complete! Best model saved as 'best_efficientnet_fold2.pth'
----------------------------------------------------------------------
  EfficientNetB0 Fold 2 - Val Acc: 99.03%

Training Custom CNN-20...

Starting training for cnn20_fold2...
----------------------------------------------------------------------
Epoch  1/10 | Train Loss: 3.1263 Acc:  13.39% | Val Loss: 2.4987 Acc:  22.52% ✓ [Best: 22.52%]
Epoch  2/10 | Train Loss: 2.4220 Acc:  24.71% | Val Loss: 2.0196 Acc:  36.72% ✓ [Best: 36.72%]
Epoch  3/10 | Train Loss: 2.2185 Acc:  30.20% | Val Loss: 1.9415 Acc:  35.71%
Epoch  4/10 | Train Loss: 2.0885 Acc:  33.45% | Val Loss: 1.6901 Acc:  45.70% ✓ [Best: 45.70%]
Epoch  5/10 | Train Loss: 1.8768 Acc:  39.84% | Val Loss: 1.5398 Acc:  48.40% ✓ [Best: 48.40%]
Epoch  6/10 | Train Loss: 1.7464 Acc:  43.52% | Val Loss: 1.6394 Acc:  47.65%
Epoch  7/10 | Train Loss: 1.5919 Acc:  48.44% | Val Loss: 1.5532 Acc:  56.14% ✓ [Best: 56.14%]
Epoch  8/10 | Train Loss: 1.4624 Acc:  53.03% | Val Loss: 1.2494 Acc:  62.13% ✓ [Best: 62.13%]
Epoch  9/10 | Train Loss: 1.3556 Acc:  56.96% | Val Loss: 0.9874 Acc:  66.19% ✓ [Best: 66.19%]
Epoch 10/10 | Train Loss: 1.2178 Acc:  60.80% | Val Loss: 0.9097 Acc:  71.84% ✓ [Best: 71.84%]

Training complete! Best model saved as 'best_cnn20_fold2.pth'
----------------------------------------------------------------------
  Custom CNN-20 Fold 2 - Val Acc: 71.84%

======================== FOLD 3/5 ========================

Training ResNet50...

Starting training for resnet50_fold3...
----------------------------------------------------------------------
Epoch  1/10 | Train Loss: 0.3516 Acc:  88.81% | Val Loss: 0.1842 Acc:  94.09% ✓ [Best: 94.09%]
Epoch  2/10 | Train Loss: 0.1588 Acc:  94.83% | Val Loss: 0.1180 Acc:  96.11% ✓ [Best: 96.11%]
Epoch  3/10 | Train Loss: 0.1348 Acc:  95.56% | Val Loss: 0.1165 Acc:  96.17% ✓ [Best: 96.17%]
Epoch  4/10 | Train Loss: 0.1031 Acc:  96.59% | Val Loss: 0.1287 Acc:  96.11%
Epoch  5/10 | Train Loss: 0.1024 Acc:  96.69% | Val Loss: 0.2501 Acc:  93.06%
Epoch  6/10 | Train Loss: 0.0958 Acc:  96.88% | Val Loss: 0.1435 Acc:  95.08%

Early stopping at epoch 6
Best validation accuracy: 96.17% (epoch 3)

Training complete! Best model saved as 'best_resnet50_fold3.pth'
----------------------------------------------------------------------
  ResNet50 Fold 3 - Val Acc: 96.17%
```

```
Training EfficientNetB0...

Starting training for efficientnet_fold3...
----------------------------------------------------------------------
Epoch  1/10 | Train Loss: 0.2924 Acc:  92.50% | Val Loss: 0.0674 Acc:  97.68% ✓ [Best: 97.68%]
Epoch  2/10 | Train Loss: 0.0663 Acc:  97.80% | Val Loss: 0.0453 Acc:  98.64% ✓ [Best: 98.64%]
Epoch  3/10 | Train Loss: 0.0508 Acc:  98.34% | Val Loss: 0.0351 Acc:  99.07% ✓ [Best: 99.07%]
Epoch  4/10 | Train Loss: 0.0374 Acc:  98.77% | Val Loss: 0.0376 Acc:  98.81%
Epoch  5/10 | Train Loss: 0.0499 Acc:  98.35% | Val Loss: 0.0268 Acc:  99.18% ✓ [Best: 99.18%]
Epoch  6/10 | Train Loss: 0.0359 Acc:  98.85% | Val Loss: 0.0507 Acc:  98.45%
Epoch  7/10 | Train Loss: 0.0340 Acc:  98.92% | Val Loss: 0.0262 Acc:  99.21% ✓ [Best: 99.21%]
Epoch  8/10 | Train Loss: 0.0360 Acc:  98.83% | Val Loss: 0.0230 Acc:  99.29% ✓ [Best: 99.29%]
Epoch  9/10 | Train Loss: 0.0323 Acc:  98.95% | Val Loss: 0.0338 Acc:  99.01%
Epoch 10/10 | Train Loss: 0.0321 Acc:  98.93% | Val Loss: 0.0387 Acc:  98.97%

Training complete! Best model saved as 'best_efficientnet_fold3.pth'
----------------------------------------------------------------------
  EfficientNetB0 Fold 3 - Val Acc: 99.29%

Training Custom CNN-20...

Starting training for cnn20_fold3...
----------------------------------------------------------------------
Epoch  1/10 | Train Loss: 3.2298 Acc:   8.33% | Val Loss: 2.8346 Acc:  12.73% ✓ [Best: 12.73%]
Epoch  2/10 | Train Loss: 2.7078 Acc:  15.81% | Val Loss: 2.5380 Acc:  18.86% ✓ [Best: 18.86%]
Epoch  3/10 | Train Loss: 2.3601 Acc:  25.29% | Val Loss: 1.9123 Acc:  37.39% ✓ [Best: 37.39%]
Epoch  4/10 | Train Loss: 2.1563 Acc:  31.92% | Val Loss: 1.8826 Acc:  39.58% ✓ [Best: 39.58%]
Epoch  5/10 | Train Loss: 1.9984 Acc:  37.92% | Val Loss: 1.6802 Acc:  47.69% ✓ [Best: 47.69%]
Epoch  6/10 | Train Loss: 1.8369 Acc:  43.74% | Val Loss: 1.5796 Acc:  51.91% ✓ [Best: 51.91%]
Epoch  7/10 | Train Loss: 1.6531 Acc:  49.74% | Val Loss: 1.4531 Acc:  55.65% ✓ [Best: 55.65%]
Epoch  8/10 | Train Loss: 1.5948 Acc:  52.14% | Val Loss: 1.9806 Acc:  39.14%
Epoch  9/10 | Train Loss: 1.5156 Acc:  53.69% | Val Loss: 1.0792 Acc:  67.29% ✓ [Best: 67.29%]
Epoch 10/10 | Train Loss: 1.3284 Acc:  59.23% | Val Loss: 0.9771 Acc:  69.92% ✓ [Best: 69.92%]

Training complete! Best model saved as 'best_cnn20_fold3.pth'
----------------------------------------------------------------------
  Custom CNN-20 Fold 3 - Val Acc: 69.92%

======================== FOLD 4/5 ========================

Training ResNet50...

Starting training for resnet50_fold4...
----------------------------------------------------------------------
Epoch  1/10 | Train Loss: 0.3543 Acc:  88.90% | Val Loss: 0.3924 Acc:  87.99% ✓ [Best: 87.99%]
Epoch  2/10 | Train Loss: 0.1582 Acc:  94.84% | Val Loss: 0.1651 Acc:  94.94% ✓ [Best: 94.94%]
Epoch  3/10 | Train Loss: 0.1300 Acc:  95.84% | Val Loss: 0.1488 Acc:  95.35% ✓ [Best: 95.35%]
Epoch  4/10 | Train Loss: 0.1042 Acc:  96.57% | Val Loss: 0.0827 Acc:  97.53% ✓ [Best: 97.53%]
Epoch  5/10 | Train Loss: 0.1009 Acc:  96.74% | Val Loss: 0.1407 Acc:  95.20%
Epoch  6/10 | Train Loss: 0.0865 Acc:  97.21% | Val Loss: 0.0843 Acc:  97.24%
Epoch  7/10 | Train Loss: 0.0856 Acc:  97.26% | Val Loss: 0.0905 Acc:  97.05%

Early stopping at epoch 7
Best validation accuracy: 97.53% (epoch 4)

Training complete! Best model saved as 'best_resnet50_fold4.pth'
----------------------------------------------------------------------
  ResNet50 Fold 4 - Val Acc: 97.53%

Training EfficientNetB0...

Starting training for efficientnet_fold4...
----------------------------------------------------------------------
Epoch  1/10 | Train Loss: 0.2952 Acc:  92.21% | Val Loss: 0.0629 Acc:  97.98% ✓ [Best: 97.98%]
Epoch  2/10 | Train Loss: 0.0639 Acc:  97.87% | Val Loss: 0.0347 Acc:  98.93% ✓ [Best: 98.93%]
Epoch  3/10 | Train Loss: 0.0522 Acc:  98.33% | Val Loss: 0.0280 Acc:  99.03% ✓ [Best: 99.03%]
Epoch  4/10 | Train Loss: 0.0424 Acc:  98.66% | Val Loss: 0.0602 Acc:  98.22%
Epoch  5/10 | Train Loss: 0.0459 Acc:  98.55% | Val Loss: 0.0754 Acc:  97.56%
Epoch  6/10 | Train Loss: 0.0408 Acc:  98.71% | Val Loss: 0.0419 Acc:  98.86%
```

```
Early stopping at epoch 6
Best validation accuracy: 99.03% (epoch 3)

Training complete! Best model saved as 'best_efficientnet_fold4.pth'
----------------------------------------------------------------------
  EfficientNetB0 Fold 4 - Val Acc: 99.03%

Training Custom CNN-20...

Starting training for cnn20_fold4...
----------------------------------------------------------------------
Epoch  1/10 | Train Loss: 3.2631 Acc:  10.01% | Val Loss: 2.5707 Acc:  19.10% ✓ [Best: 19.10%]
Epoch  2/10 | Train Loss: 2.5655 Acc:  19.89% | Val Loss: 2.4146 Acc:  24.45% ✓ [Best: 24.45%]
Epoch  3/10 | Train Loss: 2.2844 Acc:  28.99% | Val Loss: 2.1241 Acc:  31.36% ✓ [Best: 31.36%]
Epoch  4/10 | Train Loss: 2.1282 Acc:  33.85% | Val Loss: 2.1609 Acc:  32.27% ✓ [Best: 32.27%]
Epoch  5/10 | Train Loss: 1.9515 Acc:  39.08% | Val Loss: 1.7266 Acc:  42.53% ✓ [Best: 42.53%]
Epoch  6/10 | Train Loss: 1.7391 Acc:  45.95% | Val Loss: 1.2811 Acc:  61.69% ✓ [Best: 61.69%]
Epoch  7/10 | Train Loss: 1.6326 Acc:  49.60% | Val Loss: 1.1789 Acc:  65.24% ✓ [Best: 65.24%]
Epoch  8/10 | Train Loss: 1.4988 Acc:  53.52% | Val Loss: 1.1720 Acc:  64.21%
Epoch  9/10 | Train Loss: 1.4008 Acc:  56.98% | Val Loss: 1.2685 Acc:  60.18%
Epoch 10/10 | Train Loss: 1.2918 Acc:  59.94% | Val Loss: 1.1875 Acc:  62.44%

Early stopping at epoch 10
Best validation accuracy: 65.24% (epoch 7)

Training complete! Best model saved as 'best_cnn20_fold4.pth'
----------------------------------------------------------------------
  Custom CNN-20 Fold 4 - Val Acc: 65.24%

========================= FOLD 5/5 =========================

Training ResNet50...

Starting training for resnet50_fold5...
----------------------------------------------------------------------
Epoch  1/10 | Train Loss: 0.3758 Acc:  88.07% | Val Loss: 0.2389 Acc:  91.90% ✓ [Best: 91.90%]
Epoch  2/10 | Train Loss: 0.1469 Acc:  95.18% | Val Loss: 0.2586 Acc:  91.78%
Epoch  3/10 | Train Loss: 0.1298 Acc:  95.68% | Val Loss: 0.1530 Acc:  95.00% ✓ [Best: 95.00%]
Epoch  4/10 | Train Loss: 0.1070 Acc:  96.47% | Val Loss: 0.2073 Acc:  93.99%
Epoch  5/10 | Train Loss: 0.0995 Acc:  96.75% | Val Loss: 0.1123 Acc:  95.94% ✓ [Best: 95.94%]
Epoch  6/10 | Train Loss: 0.0928 Acc:  96.92% | Val Loss: 0.0804 Acc:  97.32% ✓ [Best: 97.32%]
Epoch  7/10 | Train Loss: 0.0855 Acc:  97.24% | Val Loss: 0.0933 Acc:  96.54%
Epoch  8/10 | Train Loss: 0.0749 Acc:  97.49% | Val Loss: 0.1639 Acc:  94.76%
Epoch  9/10 | Train Loss: 0.0810 Acc:  97.40% | Val Loss: 0.1036 Acc:  96.92%

Early stopping at epoch 9
Best validation accuracy: 97.32% (epoch 6)

Training complete! Best model saved as 'best_resnet50_fold5.pth'
----------------------------------------------------------------------
  ResNet50 Fold 5 - Val Acc: 97.32%

Training EfficientNetB0...

Starting training for efficientnet_fold5...
----------------------------------------------------------------------
Epoch  1/10 | Train Loss: 0.2902 Acc:  92.37% | Val Loss: 0.0508 Acc:  98.39% ✓ [Best: 98.39%]
Epoch  2/10 | Train Loss: 0.0649 Acc:  97.92% | Val Loss: 0.0264 Acc:  99.18% ✓ [Best: 99.18%]
Epoch  3/10 | Train Loss: 0.0494 Acc:  98.44% | Val Loss: 0.0412 Acc:  98.52%
Epoch  4/10 | Train Loss: 0.0431 Acc:  98.62% | Val Loss: 0.0511 Acc:  98.35%
Epoch  5/10 | Train Loss: 0.0417 Acc:  98.73% | Val Loss: 0.0493 Acc:  98.47%

Early stopping at epoch 5
Best validation accuracy: 99.18% (epoch 2)

Training complete! Best model saved as 'best_efficientnet_fold5.pth'
----------------------------------------------------------------------
  EfficientNetB0 Fold 5 - Val Acc: 99.18%

Training Custom CNN-20...
```

```
Starting training for cnn20_fold5...
----------------------------------------------------------------------
Epoch  1/10 | Train Loss: 3.2217 Acc:  12.68% | Val Loss: 2.6452 Acc:  18.34% ✓ [Best: 18.34%]
Epoch  2/10 | Train Loss: 2.5674 Acc:  20.71% | Val Loss: 2.4681 Acc:  24.94% ✓ [Best: 24.94%]
Epoch  3/10 | Train Loss: 2.2999 Acc:  27.31% | Val Loss: 2.1129 Acc:  31.71% ✓ [Best: 31.71%]
Epoch  4/10 | Train Loss: 2.0843 Acc:  33.42% | Val Loss: 2.2440 Acc:  26.51%
Epoch  5/10 | Train Loss: 1.9308 Acc:  37.84% | Val Loss: 1.7241 Acc:  44.67% ✓ [Best: 44.67%]
Epoch  6/10 | Train Loss: 1.7690 Acc:  43.90% | Val Loss: 1.7763 Acc:  45.91% ✓ [Best: 45.91%]
Epoch  7/10 | Train Loss: 1.6568 Acc:  47.25% | Val Loss: 1.5969 Acc:  47.55% ✓ [Best: 47.55%]
Epoch  8/10 | Train Loss: 1.5353 Acc:  51.57% | Val Loss: 1.2463 Acc:  61.37% ✓ [Best: 61.37%]
Epoch  9/10 | Train Loss: 1.4272 Acc:  54.47% | Val Loss: 1.0627 Acc:  65.37% ✓ [Best: 65.37%]
Epoch 10/10 | Train Loss: 1.3351 Acc:  57.57% | Val Loss: 1.2970 Acc:  58.92%

Training complete! Best model saved as 'best_cnn20_fold5.pth'
----------------------------------------------------------------------
  Custom CNN-20 Fold 5 - Val Acc: 65.37%
```

Per-Fold Results:

	Fold	ResNet50 Acc (%)	EfficientNetB0 Acc (%)	CNN-20 Acc (%)	ResNet50 Loss	EfficientNetB0 Loss	CNN-20 Loss	ResNet50 Top-3 Acc (%)	EfficientNetB0 Top-3 Acc (%)	CNN-20 Top-3 Acc (%)
0	Fold 1	95.01	99.07	56.54	0.1541	0.0323	1.5907	99.48	99.96	78.92
1	Fold 2	97.68	99.03	71.84	0.0661	0.0277	0.9097	99.92	100.00	91.96
2	Fold 3	96.17	99.29	69.92	0.1165	0.0230	0.9771	99.76	99.94	88.33
3	Fold 4	97.53	99.03	65.24	0.0827	0.0280	1.1789	99.82	99.99	85.67
4	Fold 5	97.32	99.18	65.37	0.0804	0.0264	1.0627	99.93	99.96	87.93

Average Across All Folds:

Model	Avg Accuracy (%)	Std Accuracy	Avg Loss	Avg Top-3 Acc (%)
ResNet50	96.74	1.01	0.1000	99.78
EfficientNetB0	99.12	0.10	0.0275	99.97
Custom CNN-20	65.78	5.28	1.1438	86.56

7. Export Notebook to HTML